PB-213 010

Field Operations and Enforcement Manual for Air Pollution Control

Vol. 3 inspection procedures for specific industries

Pacific Environmental Services, Inc.

prepared for

Environmental Protection Agency

AUGUST 1972

Distributed By:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

BIBLIOGRAPHIC DATA SHEET

1. Report No. APTD-1102

2.

3. Recipient's Accession No. PB-213 010

4. Title and Subtitle
Field Operations and Enforcement Manual for Air Pollution Control Volume III: Inspection Procedures for Specific Industries

5. Report Date
August 1972

6.

7. Author(s)
Melvin I. Weisburd

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Pacific Environmental Services, Inc., 2932 Wilshire Boulevard,
Santa Monica, California 90403 and
System Development Corporation, 2500 Colorado Avenue, Santa
Monica, California 90406

10. Project/Task/Work Unit No.

11. Contract/Grant No.
CPA 70-122

12. Sponsoring Organization Name and Address
ENVIRONMENTAL PROTECTION AGENCY
Office of Air Programs
Stationary Source Pollution Control Programs
Research Triangle Park, North Carolina 27711

13. Type of Report & Period Covered

14.

15. Supplementary Notes Details of illustrations in this document may be better studied on microfiche.

16. Abstracts

The Field Operations and Enforcement Manual for Air Pollution Control, Volume III explains in detail the following: inspection procedures for specific sources, kraft pulp mills, animal rendering, steel mill furnaces, coking operations, petroleum refineries, chemical plants, non-ferrous smelting and refining, foundries, cement plants, aluminum reduction plants, mining, coal preparation, fertilizer industry, paint and varnish manufacturing, galvanizing operations, roofing plants, and asphalt batch operations.

17. Key Words and Document Analysis. 17a. Descriptors

Air pollution
Manual
Abatement
Field tests
Operations
Sources
Inspection
Sulfate pulping
Animal husbandry
Waste disposal
Furnaces
Steel plants
Coking
Petroleum industry
Chemical plants
Smelting
Iron alloys
Foundries
Foundry practice
Cements
Aluminum industry
Mining
Coal preparation
Fertilizers
Paints
Varnishes
Zinc coatings
Roofing
Asphalt plants
Bituminous concretes

17b. Identifiers/Open-Ended Terms

Animal rendering

17c. COSATI Field/Group 13B

18. Availability Statement
Unlimited

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page
UNCLASSIFIED

21. No. of Pages
471

22. Price
$10.60

1a

FORM NTIS-35 (REV. 3-72)

THIS FORM MAY BE REPRODUCED

USCOMM-DC

APTD-1102

PB 213 010

FIELD OPERATIONS AND ENFORCEMENT MANUAL FOR AIR POLLUTION CONTROL

VOLUME III:

INSPECTION PROCEDURES FOR SPECIFIC INDUSTRIES

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air Programs
Stationary Source Pollution Control Programs
Research Triangle Park, North Carolina 27711

J.S.

472

APTD-1102

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Prepared by
Melvin I. Weisburd
Pacific Environmental Services, Inc.
2932 Wilshire Boulevard
Santa Monica, California 90403

for

System Development Corporation
2500 Colorado Avenue
Santa Monica, California 90406

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Office of Air Programs Publication No. APTD-1102

The Field Operations and Enforcement Manual for Air Pollution Control is divided into three separate volumes.

Volume I, Organization and Basic Procedures, contains Chapters 1 through 4.

Volume II, Control Technology and General Source Inspection, contains Chapters 5 and 6.

Volume III, Inspection Procedures for Specific Industries, contains Chapter 7.

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CHAPTER 7

INSPECTION PROCEDURES FOR SPECIFIC SOURCES

I. INTRODUCTION

Specific sources of air pollution, described in this chapter, are comprised of industrial facilities which may be major targets of air pollution control, are significant contributors to air pollution as stationary point sources and are of such complexity that training and familiarization on the part of the enforcement officer is required before he can assume complete responsibility for the inspection of these plants.

Major metallurgical, chemical processing, mining and other industries which contribute to the full range of air pollution, including smoke, fumes, dust, odor, gases and vapors, are described in this chapter. Although not all industries of possible interest are treated, the operations described are typical of stationary sources in general and should help to prepare enforcement officers in entering and inspecting other facilities that may be unfamiliar to them.

In general, each stationary source section of this chapter is broken down as follows:

- Nature of Source
- Process Description
- Emissions
- Controls
- Inspection Points

II. KRAFT PULP MILLS

A. NATURE OF SOURCE PROBLEM

Of the major pulping processes--Kraft, sulfite and neutral sulfite semichemical (NSSC)--Kraft is most significant from the standpoint of air pollution. As of 1968, Kraft mills produced 75% of the domestic pulp in 116 mills with a total production capacity of 32 million short tons. They will produce 85% of the total pulp or 60 million short tons by 1985.(1)

Kraft mills present a complex air pollution problem in terms of the variety and volumes of contaminants emitted. The major problems are odors and particulates. The malodorous contaminants are inherently objectionable and persistent at low concentrations (1 to 10 parts per billion); are non-condensible and hence difficult to control; and are emitted in large quantities.

B. PROCESS DESCRIPTION

The major sources of pollution in a Kraft mill are concentrated in the cooking of the pulp and recovery of the process chemicals. An overview of the cooking and recovery cycle and contaminants emitted from specific process points is illustrated in Figure 7.2.1. Average uncontrolled emissions from Kraft mills are shown in Table 7.2.1. Table 7.2.2 lists typical control equipment and emission rates. Emission rates and production capacities, as well as the details of process system design and operation will vary considerably among Kraft mills.

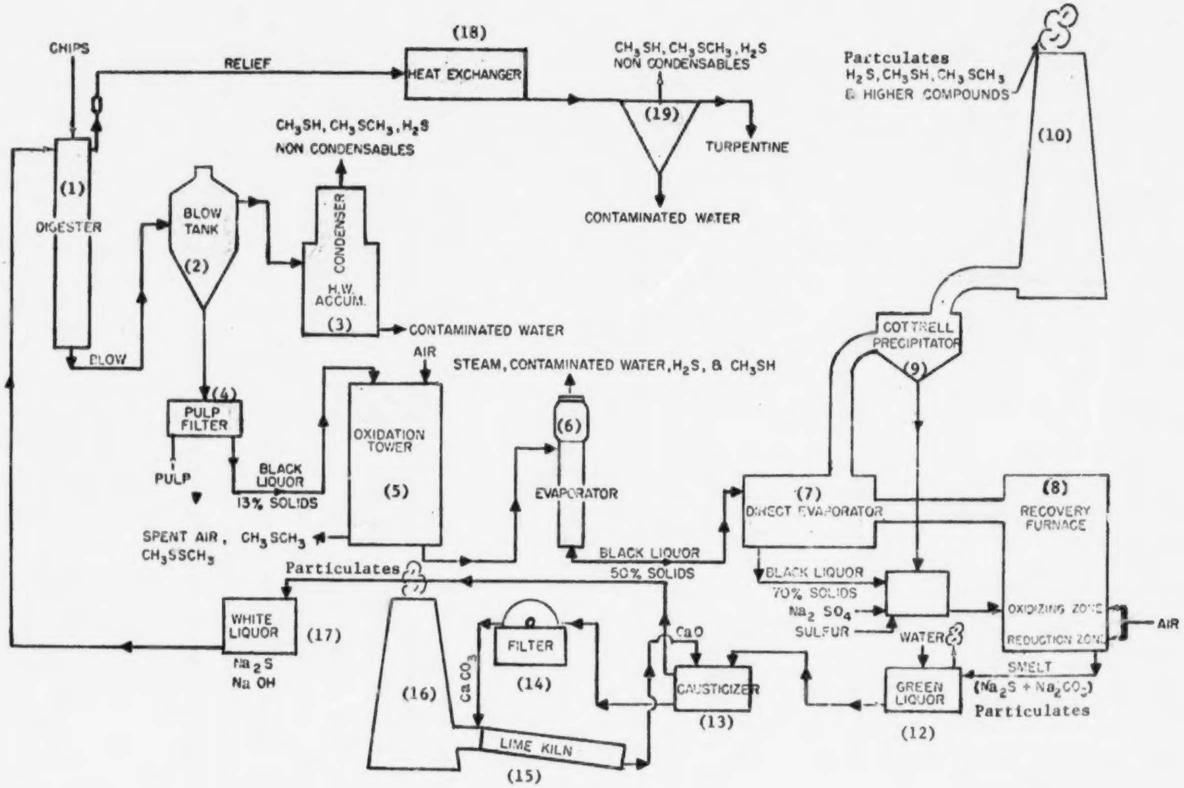

CHIPS
RELIEF
(18)
HEAT EXCHANGER
CH_3SH, CH_3SCH_3, H_2S
NON CONDENSABLES
(19)
TURPENTINE
CONTAMINATED WATER
Particulates
H_2S, CH_3SH, CH_3SCH_3
& HIGHER COMPOUNDS
(10)
(1)
DIGESTER
BLOW
BLOW TANK
(2)
CH_3SH, CH_3SCH_3, H_2S
NON CONDENSABLES
CONDENSER
H.W. ACCUM.
(3)
CONTAMINATED WATER
COTTRELL PRECIPITATOR
(9)
AIR
STEAM, CONTAMINATED WATER, H_2S, & CH_3SH
(4)
PULP FILTER
PULP
BLACK LIQUOR
13% SOLIDS
OXIDATION TOWER
(5)
(6)
EVAPORATOR
SPENT AIR, CH_3SCH_3
CH_3SSCH_3
(7)
DIRECT EVAPORATOR
(8)
RECOVERY FURNACE
BLACK LIQUOR
50% SOLIDS
BLACK LIQUOR
70% SOLIDS
Na_2SO_4
SULFUR
WATER
OXIDIZING ZONE
REDUCTION ZONE
AIR
Particulates
WHITE LIQUOR
(17)
Na_2S
$NaOH$
(16)
$CaCO_3$
FILTER
(14)
CaO
CAUSTICIZER
(13)
GREEN LIQUOR
(12)
SMELT
$(Na_2S + Na_2CO_3)$
Particulates
LIME KILN
(15)

Figure 7.2.1. FLOW DIAGRAM OF A KRAFT PULPING PROCESS SHOWING PRINCIPAL EMISSIONS AT DIFFERENT POINTS (SOURCE: WASHINGTON STATE AND DOUGLASS, References 2 and 3)

Table 7.2.1. AVERAGE KRAFT PULP MILL POTENTIAL EMISSIONS

Department	Total Vol. SCF (1)/T**	Water Vapor lb/T**	Particulate lb/T**	TRS*** lb/T(2)
Digester (1, 2, 3)				
Batch	300	2,500	0	2.5
Continuous	150	1,500	0	1.5
Washers (4)	70,000	250	0	0.5
Bleach Plant	80,000	220	0	2.4
Evaporators (6, 7)	300	–	0	3.5
Recovery Furnace (8)	330,000	4,300	170	10.0
Dissolving Tank (12)	30,000	700	5	0.15
Lime Kiln (15, 16)	45,000	850	45	1.0
Power Boiler* (Hog Fuel)	300,000	3,000	35	0.01
Paper Machine*	430,000	2,700	0	0
(Numbers reference Figure 7.2.1)		Total	255	21.6

(1) SCF - Cubic feet at standard conditions of 1 atmosphere and 68°F

(2) Does not include SO_2

(3) Six-stage bleach plant

(4) Chlorine as lb/T

*Not shown on drawing.

**Total reduced sulfur (see definition in text).

***All cooking and chemical recovery operations are in terms of amount of emission per air dried ton of unbleached pulp produced.

(SOURCE: WASHINGTON STATE AND HOUGH AND GROSS,
References 2 and 3.)

Table 7.2.2. AVERAGE KRAFT PULP MILL AIR EMISSIONS WITH CONTROL

Source (See Figure 7.2.1)	Air Pollution Controls	Total Vol. SCF/T[a]	Water Vapor lb/T	Particulate lb/T	Sulfur lb/T(1)
Digesters (1,2,3)	Thermal oxidation of non-condensibles in lime kiln, steam or air stripping of condensates				
Batch		-	-	-	-
Continuous		-	-	-	-
Washers (4)	Thermal oxidation	-	-	-	-
Bleach Plant	N. S.(2)	80,000	220	-	-
B. L. Oxidation (5)	None	35,000	700	-	0.3
Evaporators (6,7)	Caustic scrubbing plus thermal oxidation of non-condensibles				
Recovery Furnace (8)	(3)	330,000	4,300	3.5	1.0
Dissolving Tank (12)	Packed tower (4)	30,000	700	0.5	0.1
Lime Kiln (15,16)	Venturi scrubber	45,000	1,350	1.0	0.2
Power Boiler (Hog Fuel)	Cyclones	300,000	3,000	5.0	0.01
Paper Machine	N. S.(2)	400,000	1,600	-	-
(numbers reference Figure 7.2.1)		Total	11,870	10.0	1.6

(1) Does not include sulfur as SO_2

(2) Not specified
(3) No direct contact evaporators; electrostatic precipitators employed for particulate removal
(4) Employs weak wash as scrubbing medium

a. Probably wet, judging from figure given for recovery furnace volume, 330,000 scf/ton.

(SOURCE: WASHINGTON STATE AND HOUGH AND GROSS,
References 2 and 3.)

1. Pulp Cooking

Wood chips or saw dust together with the cooking chemicals or white liquor are fed to the digesters ((1) in Figure 7.2.1). The digesters are tall cylindrical vessels of 10-20 ton capacity. Cooking is typically conducted at temperatures around 350°F and 110 lbs. per square inch gauge pressure for 3 to 4 hours on either a batch or a continuous basis.

The cooking solution consists of approximately 1/3 sodium sulfide and 2/3 caustic soda (sodium hydroxide). The caustic soda serves to dissolve the intercellular material (lignin) which naturally binds the wood fibers together. Sodium sulfide reacts with the cellulose to impart strength to the ultimate product and with the waste wood products to produce the air pollution problems characteristic of the Kraft process.

At the completion of the cooking cycle the contents are blown into the blow tank. The pulp stock is screened to remove knots and undissolved wood chips and is washed. The stock then enters the bleaching and paper production sequence.

The digester is a major source of odorous contaminants, particularly mercaptans and other gases such as methanol, which are released with steam from digester pop valves, the blow tank, feeder vents, and accumulator vents ((2) in Figure 7.2.1).

a. Controls

Non-condensible vapors can be vented to the lime kiln, hog fuel boilers, or to specially constructed gas fired furnaces. In many operations of this type, condensers (surface or barometric) must be applied to remove water and other condensible vapors prior to burning ((3) in Figure 7.2.1). Non-condensible vapors may be stored in a gas holder or surge tank such as the Vaporsphere to provide continuous fuel flow to the combustion equipment. Non-condensible gases from certain operations at some facilities can be vented to the recovery furnace for firing, as long as these are low volume sources. For example, gases from brown stock washers can possibly be burned in the recovery furnace without creating an explosion hazard.

2. Initial Chemical Recovery

The spent black liquor is separated from the pulp at the stock washer. The weak black liquor is first concentrated in steam-heated multiple-effect evaporators (6) which increases the solid content from about 15 percent to 55 to 60 percent in the strong black liquor leaving the evaporators, as shown in Figure 7.2.2. The solid content is further increased to 60 to 70 percent in the direct contact evaporator where the liquor is dehydrated by direct contact with the flue gases from the recovery furnace. Substantial emissions of hydrogen sulfide and other malodors are released from the condenser following the multiple-effect evaporators, from hot wells or seal tanks and from the stack of the recovery furnace, in the case of the direct contact evaporator. Emissions from the furnace are largely due to stripping of hydrogen sulfide by carbon dioxide contained in the flue gases. The amount of the emission depends on how the recovery furnace is operated.

The black liquor is now sufficiently concentrated to support combustion and is sprayed into the recovery furnace (8) through vertically oscillating nozzles. The inorganic constituents, sodium sulfide and sodium carbonate, are reduced in the lower reduction zone of the furnace and settle out in a molten state or smelt on the furnace grates. The sulfur organics are oxidized in the upper zone of the furnace.

The operation of the recovery furnace must be optimized or balanced to recover the cooking chemicals, to dispose of the sulfur organics and to satisfy the demand for process steam as well as to control air pollution. Increased demand for steam, increased or fluctuating firing

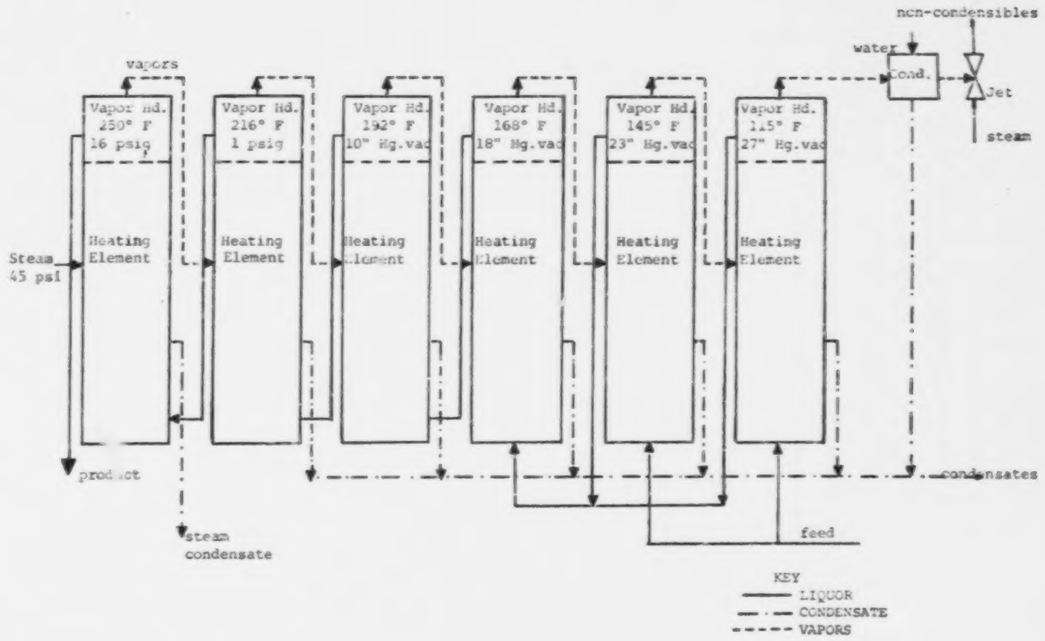

non-condensibles
water
Cond.
Jet
steam
vapors
Vapor Hd.
250° F
16 psig
Vapor Hd.
216° F
1 psig
Vapor Hd.
192° F
10" Hg.vac
Vapor Hd.
168° F
18" Hg.vac
Vapor Hd.
145° F
23" Hg.vac
Vapor Hd.
115° F
27" Hg.vac
Steam
45 psi
Heating Element
Heating Element
Heating Element
Heating Element
Heating Element
Heating Element
product
steam condensate
condensates
feed
KEY
LIQUOR
CONDENSATE
VAPORS

Figure 7.2.2. A TYPICAL MULTIPLE EFFECT EVAPORATOR SYSTEM
(SOURCE: DOUGLASS, Reference 4).

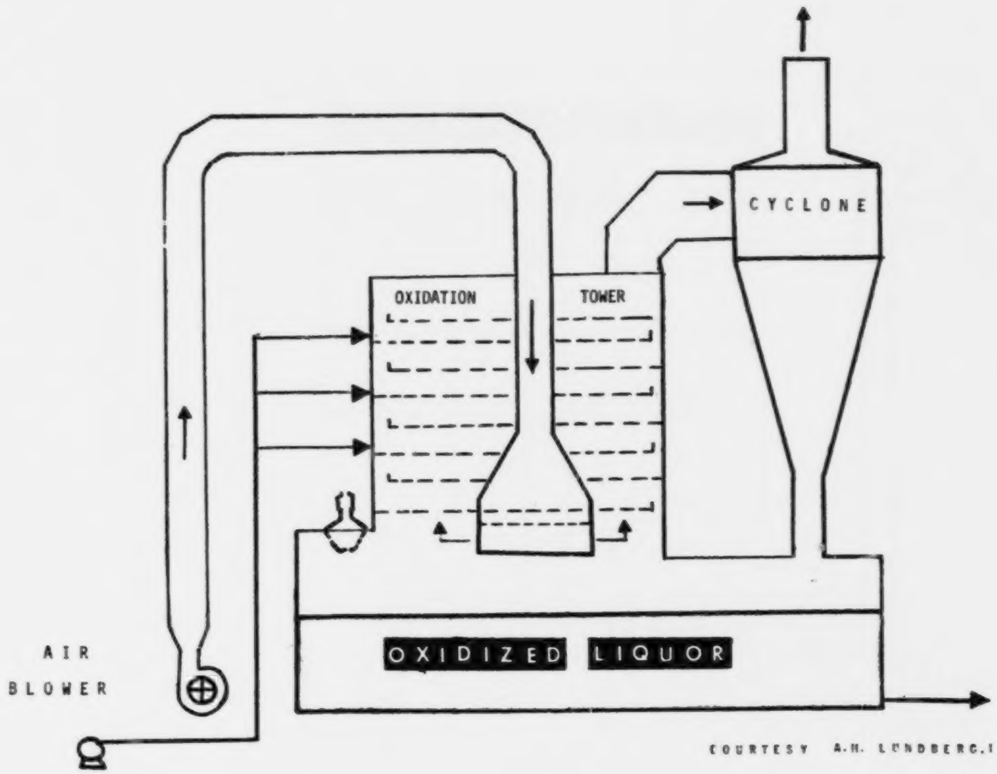
rates, or inadequate supply of primary and secondary air can cause large-scale releases of products of partial combustion. Odorants include hydrogen sulfide, mercaptans (especially methyl mercaptan), dimethyl sulfide and other organic sulfides and dimethyl disulfide and other disulfides. Particulates include sodium sulfate, sodium carbonate and carbon and may be emitted at about 170 pounds per ton of air dried pulp produced by the mill. These are particles one micron in diameter or less.(5)

a. Controls

Black Liquor Oxidation processes (5) are applied to prevent H_2S and other malodorous emissions from the evaporators. In this process, sodium sulfide is oxidized to thiosulfates, which are relatively unreactive to the carbon dioxide produced in the recovery furnace.

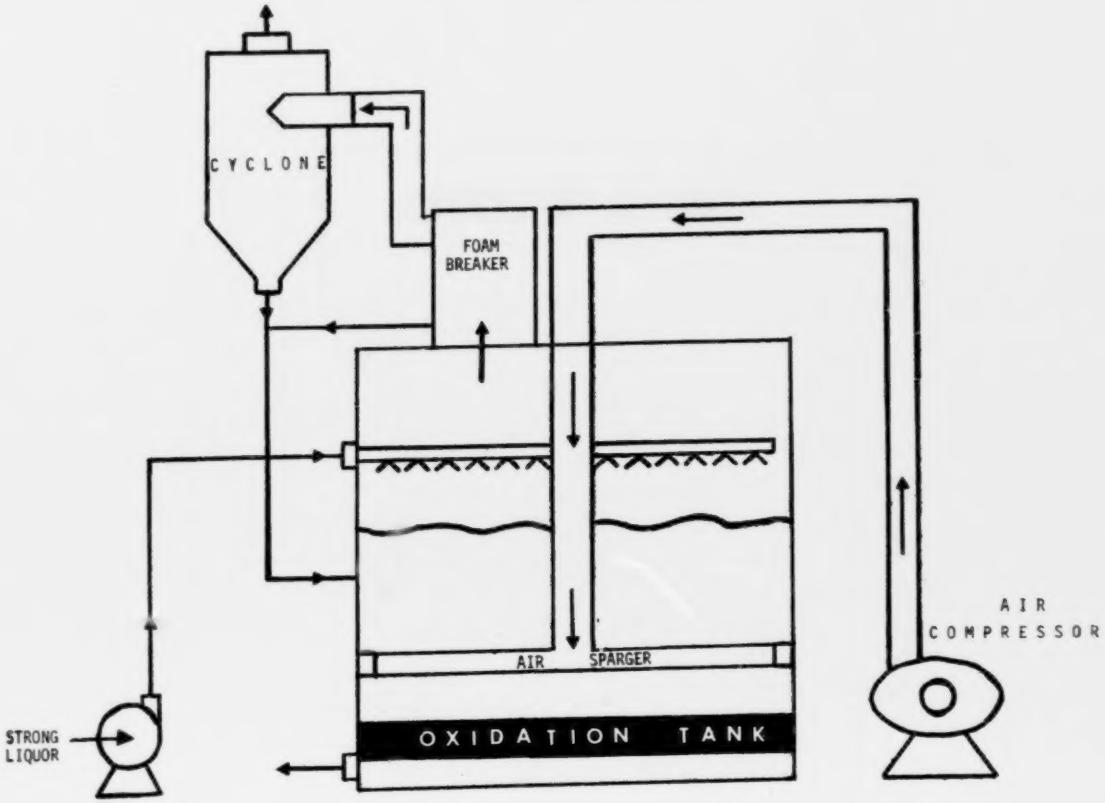
The Weak Black Liquor Oxidation Process (14 to 18 percent solids) reduces malodorous emission in the direct contact evaporator and in the multiple evaporators (Figure 7.2.3), and produces cleaner condensates. A bubble tray or packed tower provides counter-current contact between the black liquor and air. Entrained droplets are subsequently collected by cyclone. The oxidized liquor is collected in a foam tank (retention time 5 minutes), where foam is dissipated at the surface by mechanical agitators or foam breakers. The liquor is then pumped to the multiple-effect evaporators for further concentration.

Strong Black Liquor Oxidation, a more recent development,(6) is applied after the multiple-effect evaporators. The system, shown in Figure 7.2.4, introduces compressed air by means of a sparger or airheader. To reduce foaming, strong black liquor is sprayed into the top of the tank. Cyclones are used to collect entrained


AIR
BLOWER
OXIDATION
TOWER
CYCLONE
OXIDIZED LIQUOR

COURTESY A.H. LUNDBERG,INC.

Figure 7.2.3. WEAK BLACK LIQUOR OXIDATION
(SOURCE: KNUDSON, Reference 6.)


CYCLONE
FOAM BREAKER
AIR COMPRESSOR
AIR
SPARGER
OXIDATION TANK
STRONG LIQUOR

COURTESY: CHEMICO

Figure 7.2.4. STRONG BLACK LIQUOR OXIDATION
(SOURCE: KNUDSON, Reference 6.)

droplets. A retention time of over 2 hours is required. Effectiveness depends, in part, on proper recovery furnace operation to avoid excess hydrogen sulfide formation.

Polishing oxidation, instituted recently at a number of Northwest mills, is a final oxidation stage immediately before the liquor is fired. It usually is conducted in comparatively small units, like eductors or a small tank, for counteracting reversion of previously oxidized liquor.

New recovery furnaces designed to minimize emission of malodors evaporate the black liquor prior to burning in the recovery furnace by use of combustion air rather than flue gas. The hot flue gases are used in a special heat exchanger to heat the combustion air to 600°F. The heated air is then used in a direct contact evaporator to concentrate the black liquor prior to firing. The combustion air then carries any malodorous gases that are released into the furnace when they are burned.

Another design modification is the direct-firing furnace. The direct-contact evaporator is replaced by a multiple-effect evaporator system augmented with a forced circulation concentration evaporator (Figure 7.2.5). This system is capable of concentrating the black liquor to about 64 percent solids.

Chemical oxidation, although not used on recovery furnaces but on other sources indirectly helps to reduce recovery furnace emissions. A sodium carbonate-bicarbonate scrubbing medium is used to selectively remove hydrogen sulfide from flue gas and to recover the sulfur. Reduced furnace firing rates to prevent overloading of the recovery furnace and utilization of black liquor oxidation to reduce emissions from the direct-contact evaporator are also desirable. A corresponding loss of pulping production capacity may result.

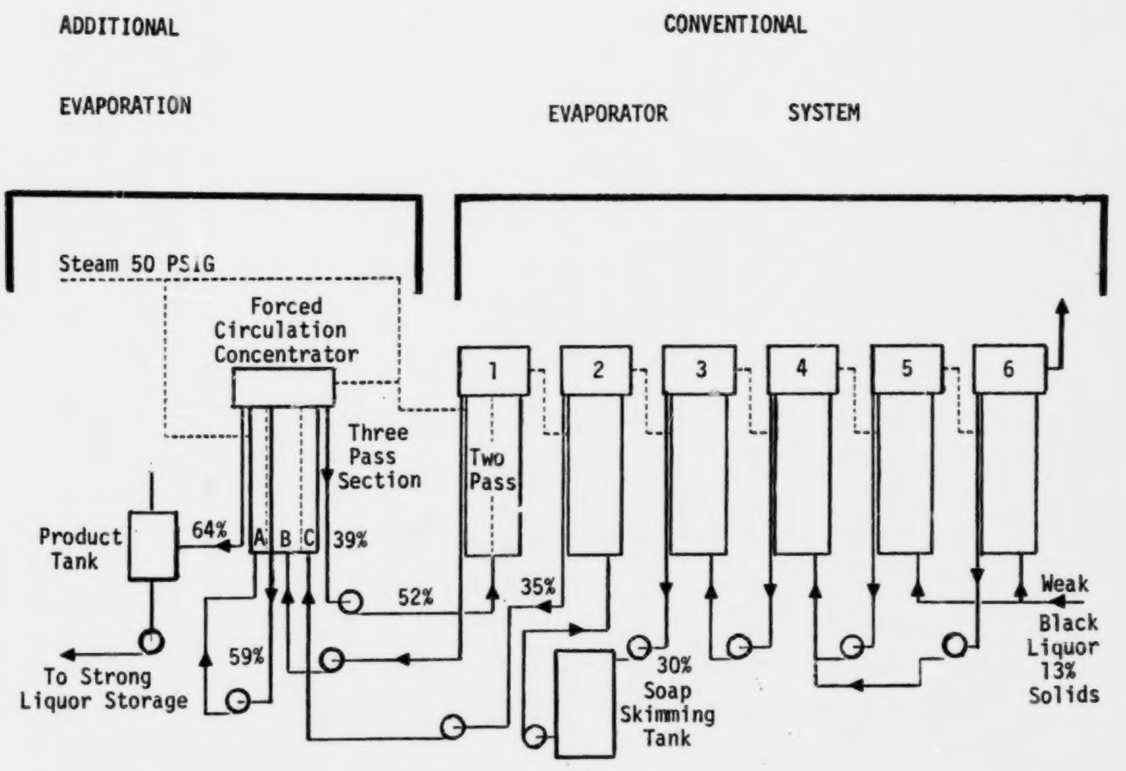

ADDITIONAL
EVAPORATION
CONVENTIONAL
EVAPORATOR
SYSTEM
Steam 50 PSIG
Forced Circulation Concentrator
Three Pass Section
A
B
C
64%
39%
52%
59%
Product Tank
To Strong Liquor Storage
1
2
3
4
5
6
Two Pass
35%
30%
Soap Skimming Tank
Weak Black Liquor 13% Solids

Figure 7.2.5. MULTIPLE EFFECT EVAPORATOR SYSTEM
(SOURCE: HENDRICKSON AND KOOGLER, Reference 1.)

Electrostatic precipitators are applied to recovery furnaces. Precipitators operate at 97+ to 99+ percent control efficiency and emit in the range of a tenth of a grain per cubic foot. Scrubbers are often additionally required to prevent precipitator snowing (discharge of agglomerated fumes not collected by the precipitator). The particle sizes emitted are easily collected by low efficiency scrubbers.

3. Final Chemical Recovery

The smelt flows in bulk from the recovery furnace to the smelt dissolving tank where it is dissolved in water and weak liquor to form green liquor, resulting in a violent release of large volumes of steam and particulates in mist or dust form (12 in Figure 7.2.1). These emissions contain highly caustic materials, particularly sodium hydroxide and sodium hydrosulfide. Uncontrolled emissions may run about 20 pounds/ton of pulp.

The green liquor is pumped to a causticizer (13 in Figure 7.2.1) where it is treated with slaked lime (calcium hydroxide), clarified and returned to the digester. Calcium carbonate precipitates from the causticizer solution as mud which is then filtered, washed and recycled to the lime kiln where it is calcined to produce lime (calcium oxide). The uncontrolled lime kiln is a major source of particulates, and can emit more than 10 tons/day from some plants. Hydrogen sulfide odors also may form from stripping of residual quantities of sodium sulfide carried over from the smelt by the carbon dioxide from the lime mud and kiln fuel.

a. Controls

Fine mesh pads and fans are used to improve performance of demisters and water showers. Venturi, packed tower, and impingement type scrubbers are also used to control smelt tank emissions.

Lime kiln emissions can be controlled by means of Venturi Scrubbers. Entrained dust particles are collected in cyclone collectors following the Venturi. Impingement scrubbers may also be used, but plugging of nozzles and orifices is frequently encountered. New fluidized bed lime kilns utilizing Venturi scrubbers for control of particulates are planned.

4. Other Mill Sources

Steam and electricity required to operate the mill are supplied from power boilers, combination boilers, and hog burners.

Power plant boilers may be fired by coal, oil or gas and the operation and pollution problems are similar to other power plant operations, described in Chapter 6, Section II of this manual. Fly ash and sulfur dioxide emissions are the primary contaminants of interest. A combination boiler is usually used to burn bark and at least one other fuel. The bark boiler or hog fuel burner is used to burn waste wood materials, including saw dust. These are usually of the Dutch Oven type equipped with low set spreader stokers. The charge is fed through chutes. Secondary air is used to control combustion, and multiclones are used to collect dust and fly ash (see Chapter 6, Section II).

C. INSPECTION POINTS

The control of Kraft emissions may be currently characterized as a best technology effort, i.e., the air pollution problem is inherent in the Kraft process, is industry-wide, and control technology continues to undergo research, development and testing. In some states, emission standards are set and compliance plans are negotiated specifically geared to the control of Kraft Mills. Emission standards are set in terms of pounds of pollutants allowed, for each specific equipment or process unit, per ton of air dried unbleached pulp (lb/ADT) processed by the plant. Malodorous gases are termed Total Reduced Sulfur or TRS, and are distinguished from sulfur oxides. Examples of emission standards in effect for the State of Washington are shown in Table 7.2.3.

Specific inspection procedures, especially the citation of violations, will depend on the control program and policies of the air pollution control agency involved. In general, the inspector performs the following functions:

- Reporting or verifying progress made by the mill in meeting compliance plan schedules.
- Assuring that day-to-day operation and maintenance practices serve to minimize pollution wherever possible.
- Reporting breakdown, shutdown or by-passing of process equipment and changes in pulp production schedules or cooking and chemical recovery procedures.
- Citing violations that are clearly flagrant in nature.
- Correlating public complaints with air quality measurements, emission rates and control practices.

The ability to distinguish between odors by character and process (e.g., direct contact evaporator, stock washer, terpentine recovery, etc.) is particularly important in view of the variability in the emission constituents. The inspector should be trained in the conduct of an odor survey (see Chapter 6, Section V).

Table 7.2.3. SUMMARY OF KRAFT MILL EMISSION STANDARDS FOR WASHINGTON STATE

SOURCE	POLLUTANT	EMISSION STANDARD ppm, dry	 lb/ton[a]	COMPLIANCE DATE
Recovery furnace(s)	Total reduced sulfur[b] (TRS)	70 and 17.5 and	2[c] 0.5[c]	d July, 1975
Recovery furnace(s)	Particulates	-	4	July, 1975
Digesters and multi-effect evaporators	Total reduced sulfur	Equivalent to reduction achieved by thermal oxidation in a lime kiln		July, 1972
Lime kiln(s)	Particulates	-	1	July, 1975
Smelt tank(s)	Particulates	-	1/2	July, 1972

a. As defined in WAC 18-36: for mills less than 200 ton/day, daily emissions equalling a 200 ton/day are allowed

b. Includes hydrogen sulfide, mercaptans, and disulfides

c. Whichever is the most restrictive

d. Compliance date adjusted by the Board to meet individual mill requirements

(SOURCE: WASHINGTON STATE, Reference 2)

1. Environmental Observations

The environment in the vicinity of Kraft mills should be periodically surveyed for odors and damage to vegetation and materials, and these findings correlated with public reactions in neighboring communities and with specific mill operations wherever possible. Damage to residences, other structures, automobile surfaces, and other materials habitually located near the mill should also be investigated.

The principal odors from a Kraft mill are characteristic in terms of their quality and pervasiveness. Tables 7.2.4 and 7.2.5 illustrate odor thresholds and qualities by sulfur compound.(1) Other odors, such as terpenes and methanol, sufficiently differ from hydrogen sulfide and mercaptans, and are easily recognized. These have the odor of terpentine or are "medicinal" in character, and tend to be localized around process equipment particularly stock washers and oxidation towers. The sulfides and mercaptans, in contrast, can be detected many miles from the plant.

The inspector should note wherever possible wind direction, wind speed, humidity and atmospheric stability in his observations and he should develop a systematic procedure for patrolling and noting the location, quality and intensity of the odor. Odors may be noted on an intensity scale or a scentometer may be used. The inspector may organize a community odor panel consisting of carefully selected citizens who may help to establish the significance of day-to-day ground level variations within the normal odor intensity range. An expert odor panel working under controlled, closed room conditions may also help to isolate the effect of possible changes in mill operations.(1) See Section V, Chapter 6, Odors.

Sulfur compounds (particularly H_2S) can discolor and damage lead based paints and paints containing mercury-based fungicides and may accelerate tarnishing of silver and copper. Dis-

Table 7.2.4. ODOR THRESHOLDS OF KRAFT MILL GASEOUS SULFUR COMPOUNDS IN AIR

ppm (by volume)

Sulfur Dioxide	1.0-5.0	(a)				
Hydrogen Sulfide	0.0085	(b),	0.0047	(a).	0.0009	(d)
Methyl Mercaptan	0.0021	(a),	0.040	(c),	0.0006	(d)
Dimethyl Sulfide	0.0001	(a),	0.0036	(c),	0.0003	(d)

(a) Leonardis, G., Kendall, D., Barnard, N., "Odor Threshold Determinators of 53 Odorant Chemicals," J.A.P.C.A. (2), 91-5, 1969.

(b) Lederlof, R., Edfor, M. L., Friberg, L., Lindvall, T., Nordisk Hygenish Tidskrfit 46, 51, 1965.

(c) Young, F. A., Adams, D. R., Sullivan, Dobbs, "The Relationship between Environmental-Demographic Variables and Olfactory Detection and Objectionability Thresholds" to be published in Perception and Psychophysics.

(d) "Handbook of Air Pollution," U.S.DHEW, PHS, Bureau of State Services, Division of Air Pollution, Cincinnati, Ohio.

(SOURCE: HENDRICKSON AND KOOGLER, Reference 1.)

Table 7.2.5. CHARACTERISTICS OF KRAFT MILL GASEOUS SULFUR COMPOUNDS

Compound	Characteristic Odor
Sulfur Dioxide	strong, suffocating
Hydrogen Sulfide	rotten eggs
Methyl Mercaptan	rotten cabbage
Dimethyl Sulfide	vegetable sulfide

(SOURCE: HENDRICKSON AND KOOGLER, Reference 1.)

coloration usually takes the form of browning or blackening of materials and is enhanced if the surfaces have been moistened or weathered, depending on the lead content. Fungi will also darken unprotected paints, so the inspector should, in doubtful cases, have the cause of damage verified by experts. Vegetation damage also may result from sulfur dioxide emitted from boiler equipment, as well as from hydrogen sulfide.

Deposits of particulates may result from the fallout of saltcake particles, fly ash, soot, burned particles and lime, which are usually confined to within 1/4 to 2 miles from the plant. Some of the fallout is of a comparatively caustic nature and can damage vegetation, materials and painted surfaces particularly on vehicles located near the plant. Particles may be sampled and taken to the laboratory for analysis to help identify the process sources responsible. Particles high in calcium are generally emitted from the lime kiln; particles high in sodium may originate from the recovery furnace and smelt tank; charred or insoluble material originates from hog burning equipment. Sodium salts, which tend to be more volatile than other particulates, may be the principal offender. Particulates which fall out as snow may be due to flocculation of particles in the electrostatic precipitator. These consist of fluffy aggregates up to 1 millimeter in diameter.(5) The larger aggregates are largely responsible for damage to paint and vegetation.

2. Observation of Exterior of Mill

Points of emissions in a Kraft mill include stacks and vents at roof level, the recesses between plant structures, inside the structures and ground level. The obvious emissions are the steam plumes and mists, particularly from the recovery furnace. These can be voluminous and may travel over great distances and altitudes. The steam and vapor emissions make it difficult to isolate and read the dry portions of the plumes. Long plumes, however, are always suspect in view of the relatively rapid dissipation of steam. Reading visible emissions, while taking into account the dry and liquid contaminants is tenable, but the practice will depend on the policy of the air pollution control agency involved.

The inspector should become familiar with the quality and intensities of odors and the visual character of mill emissions as they vary through the day and with weather conditions. Where abnormal conditions occur, source testing should be requested. Where an unusual number of public complaints are reported, the possibility of odors being released with intermittent emissions from starting up and shutting down of equipment, opening of digesters, condenser or heat recovery system failures, overloading of recovery furnace, faulty oxidation tower operations, etc., should be investigated. Vents on bleaching and other mill operations, also, should not be ignored, as highly toxic chlorine gas can be accidentially released.

3. Inspection of the Plant Interior

a. The Interview

In Kraft Mills, the interview is usually conducted with staff that has been permanently assigned to the air pollution problems of the plant. The interview should be primarily directed at ascertaining factors which affect process emissions, control progress and changes in operating procedures which cannot be noted during the physical inspection. Recording charts, logs and charts relating to process performance and emissions can be examined in the office with the air pollution staff of the mill. The inspector should clearly establish normal operating procedures in order to be able to identify abnormal or changing conditions. A procedure should be adopted and practiced by which the mill reports upsets and outages to the enforcement agency. Scheduled maintenance, especially if it involves taking control equipment out of operation, should be announced in advance.

Information obtained by interview should include:

- Type of Wood Used: resinous content, softwood, hardwood extent of use of saw dust, etc. The methyl group contained in certain sulfur based emissions derive from the methoxyl content of woods. Hardwoods contain more methoxyls than softwoods, and have greater process odor material.(7) Resinous woods can cause foaming in oxidation systems.
- Sulfidity. Malodor from the major sources of pollution in the recovery operation is generally in direct proportion to the sulfide content of the white liquor, other conditions being equal. The sulfidity may vary from 12 to 35 percent.
- Cooking Variables. Malodorous emissions can be increased when cooks are shortened and pressure and temperatures are increased.
- Pulping capacity of the mill should be determined in terms of tons of unbleached air dried pulp. The inspector should become familiar with variations in pulping capacity. Substantial increases in pulping output may cause the capacities of existing process equipment to be exceeded, including overloading of the recovery furnace, and excessive emissions from power plant and other supporting equipment.
- Plant program for monitoring emissions. The inspector should be familiar with the mill schedule for conducting source testing and maintenance of continuous monitors, such as the titrator, discussed later. It is extremely important that the equipment be kept in good working order. The inspector should clearly establish any modifications made by the plant to the instrumentation, and should assure that a formal procedure for maintaining the accuracy of continuous monitors be adopted.

- Emission inventories, negotiated compliance plans and permits. The inspector should have available with him information concerning the equipment and emission inventories of the plant to determine if significant changes have been made in any of the major sources that will affect emissions and odors. It is desirable to compare inventories, process flow diagrams, and plot plans on file with existing conditions. This can be accomplished either before or after the tour through the plant. The black liquor flow, the exact points of emission and firing rates to the recovery furnace, the lime kiln and the power boilers and hog burners, in particular, should be noted.

b. The Physical Inspection

The inspection should be organized around two closed systems: (1) the black liquor system, including the digesters, relief valves, accumulators, oxidation towers, direct contact evaporator, recovery furnace, and smelt tank, and (2) the lime kiln and the lime recycling system. The bleaching plant should also be inspected, particularly the brown stock washer where water vapor and malodorous contaminants may be collected by hood and discharged to the atmosphere.

(1) Black Liquor System

In the black liquor system, the inspector should become familiar with the vents, valves and condensers, the types of condensers, and associated odors and emissions. The design, condition and operation of the oxidation towers should be noted, as these bear on the release of odors from the furnace and the evaporators. If the foam produced in the towers is excessive, the foam breakers may become overloaded, causing them to kickout and allow foam to spill out of the tower. Systems in which air and black liquor flow concurrently generally cause less foaming than countercurrent systems.

Spills, indications of poor maintenance and low level odors should be noted at this point. The foaming action in oxidation towers can cause operational and maintenance problems especially from the use of certain softwoods such as pine and from silt. Problems include corrosion of the aluminum alloy tank construction due to the alkaline atmosphere. Also an increase in overall plant pulping capacity can cause a decrease in the oxidation rate and hence reformation of sulfides.

(2) TRS Monitors

The operation of the instrument used to monitor total reduced sulfur should be inspected. A recommended procedure for TRS measurement is the use of an electrolytic titrator monitor. This instrument is based on coulometric principles.(1,6,8,9) Readout is based on cell voltage which varies with the consumption of bromine in the electrolyte as it reacts with the reduced sulfur compounds (see Figure 7.2.6).

Sources to which the titrator are applied typically include recovery furnaces and the lime kiln or a gas-fired furnace if used for disposal of noncondensibles. Particulates are typically measured at the recovery furnace and lime kiln and smelt tank, by means of filtration followed by adsorption in a water bubbler on a batch basis, or by use of other approved continuous methods.

The recorder is usually located in the instrument room adjacent to the furnace. The location of the probe in the duct work should be checked; it is usually located after the direct contact evaporator. Titrators are temperamental

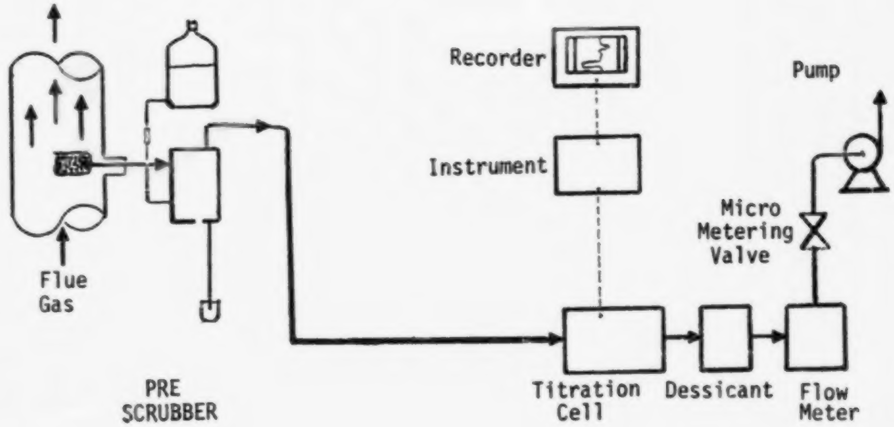

Flue
Gas
PRE
SCRUBBER
Recorder
Instrument
Titration
Cell
Dessicant
Flow
Meter
Micro
Metering
Valve
Pump

Figure 7.2.6. CONTINUOUS STACK SAMPLER FOR TRS COMPOUNDS
(SOURCE: KNUDSON, Reference 10).

instruments, and are usually modified at the plant to improve sturdiness and reliability. Empirical readings on these recorders measure up to about 1200 ppm, with a 10 percent loss of accuracy around the 1000 ppm point. Peaks on strip charts may be due to soot blowing, which may occur on a two-hour cycle, or to upsets in air ratios. The inspector should check for tight sampling points to assure absence of sample dilution.

(3) Recovery Furnace

The inspector should become familiar with the specific design and operation of the recovery furnace in the plants to which he is assigned. Many factors enter into achieving optimum combustion in the furnace from an air pollution standpoint including the firing rate, secondary air, percent excess oxygen in the flue gas, black liquor spray droplet size and time and turbulence. Factors which may be noted on inspection are excess air and secondary air, and liquor firing rates. In the recovery furnace control room the following items should be checked on the operator's log sheet or by instrument readings:

- Sulfidity of white liquor.
- Percent solids of black liquor.
- Sodium sulfide content of black liquor in and out of black liquor oxidation unit.
- Voltage and amperage readings of the electrostatic precipitator.

The following lime kiln operational data should be obtained from the log sheet:

- Sodium content of washed cake, taken once per day or shift.
- Scrubber water flow rate and source, by flow meter reading, once an hour.
- Scrubber pressure drop, by manometer.

The direct reading oxygen recording instrument should also be checked. Readings below 3 percent may indicate furnace overloading. Oxygen recording instruments will usually be located near the titrator recorder.

A furnace operating log may also be noted in the recovery furnace area which records the black liquor firing rates as well as steam output, usually every hour. This information should be correlated with recovery furnace emissions so that overloads can clearly be recognized from this performance data.

The inspector should check to see whether the air ports in the recovery furnace are regularly routed to prevent plugging and that excess oxygen and proper operating temperature (usually around 1100°F) are maintained in the upper oxidation zone of the furnace. The shutting down of secondary air for any reason can cause an increase in emissions. The inspector should recognize, however, that steps may have to be taken on occasion to prevent dangerous situations, such as furnace or digester explosions.

(4) Lime Kiln System

The lime kiln system should be checked for both particulates and odors. The make-up rate for saltcake (lbs./saltcake added per ton pulp produced) indicates how much of the sodium and saltcake is being lost to the atmosphere and to waste water reuse and/or treatment. A loss of 100 lbs. saltcake/ton pulp may be reasonable, but the proper figure must be established with each plant. This information will be found on the recovery furnace log sheet. Hydrogen sulfide can form, particularly in long kilns, due to reactions of carbon dioxide with sodium sulfide in the carbonate sludge, and to the introduction of carbonate at the cooler end of the kiln. In some plants noncondensibles from the hot water accumulators are carried to the lime kiln for incineration.

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III. ANIMAL RENDERING

A. DESCRIPTION OF SOURCE

The rendering of animal matter falls into two categories: the salvaging of edible products and the reclamation of inedible products. Similar types of processing equipment and air pollution problems are involved in both activities. This section is primarily concerned with inedible product recovery.

As unpleasant as rendering operations are, they serve a necessary as well as a beneficial community function. They provide a method for disposing of dead animals, meat cutting scraps and poultry dressing scraps which would otherwise present a health hazard.

Carcasses, meat bone scraps and offal are delivered to the rendering plant. Preparation of this matter usually consists of skinning and dissecting the dead animal into segments small enough to be fed to a hogger. Blood and feathers can also be fed to the process.

Depending on the feedstock, the processing will yield tallow from meat scraps and offal, and high protein meal for poultry feed from blood and feathers. Table 7.3.1 describes typical yields of feedstock from slaughterhouse operations.(1) The table demonstrates the potential quantities of materials that must be treated in communities where these operations are located.

B. PROCESS DESCRIPTION

Odors present the principal air pollution problem from rendering, drying and refining of animal matter. Dust from blood drying, meal grinding and

Table 7.3.1. INEDIBLE REDUCTION PROCESS RAW MATERIALS ORIGINATING FROM SLAUGHTERHOUSES

Source, lb live wt	Inedible offal and bone, lb/head	Blood, lb/head
Steers, 1,000	90 to 100	55
Cows	110 to 125	55
Calves, 200	15 to 20	5
Sheep, 80	8 to 10	4
Hogs, 200	10 to 15	7

(SOURCE: AIR POLLUTION ENGINEERING MANUAL, Reference 1.)

handling are secondary problems. Malodors emanate from most animal matter operations, especially from rendering cookers. Table 7.3.2 describes emission rates from the various equipment units and systems found in rendering operations. Table 7.3.3 quantifies odor threshold values for the substances associated with the breakdown of animal fat. Some odor threshold concentrations are in the range of 10 parts per billion.

The reduction of animal matter is carried out in captive plants as an integral part of the meat packing industry or in separate scavenger plants. A typical operation is shown in Figure 7.3.1 where skinned carcasses, bone and meat scraps are loaded into a dump pit, ground in a hogger and screw conveyed to a steam-heated cooker. Digestion takes place over a 2 to 4 hour cooking cycle on a batch or a continuous basis. The water vapor is released to the vent system and the residual hot solids are dumped into a percolator which allows the free tallow to drain to the settling tank. The cracklings, which still contain a significant quantity of tallow, are conveyed to a steam-heated press where the remaining tallow is expelled and drained to a settling tank. The remaining solids are conveyed to a surge bin or holding vessel and then ground into meal. Final tallow extraction processes can be aided by the use of soda ash or sulfuric acid to enhance phase separation. Solvent extraction techniques using hexane in a vapor tight system, with venting of the solvent vapors to condensers, can be used for extremely high quality control. Air blowing of the tallow provides for additional removal of remaining water.

Equipment configurations differ considerably among plants. Modern plants consist of continuous flow systems. The design of these systems will be largely based on capacities, types and specifications of products, and the cooking and drying processes employed. Typical processes include the following:

Table 7.3.2. ODOR CONCENTRATIONS AND EMISSION RATES FROM INEDIBLE REDUCTION PROCESSES

Source	Odor concentration, odor unit[e]/scf		Typical moisture content of feeding stocks, %	Exhaust products, scf/ton of feed[a]	Odor emission rate, odor unit/ ton of feed
	Range	Typical average			
Rendering cooker, dry-batch type[b]	5,000 to 500,000	50,000	50	20,000	1,000 x 10^6
Blood cooker, dry-batch type[b]	10,000 to 1 million	100,000	90	38,000	3,800 x 10^6
Feather drier, steamtube[c]	600 to 25,000	2,000	50	77,000	153 x 10^6
Blood spray drier[c, d]	600 to 1,000	800	60	100,000	80 x 10^6
Grease-drying tank, air blowing			< 5	100 scfm per tank	
156°F		4,500			
170°F		15,000			
225°F		60,000			

[a] Assuming 5 percent moisture in solid products of system.

[b] Noncondensable gases are neglected in determining emission rates.

[c] Exhaust gases are assumed to contain 25 percent moisture.

[d] Blood handled in spray drier before any appreciable decomposition occurs.

[e] For Definition see Odor Detection and Evaluation, Chapter 6, Section 7.

(SOURCE: AIR POLLUTION ENGINEERING MANUAL, Reference 1.)

Table 7.3.3. ODOR THRESHOLD CONCENTRATIONS OF SELECTED RENDERING COMPOUNDS

Substance	Formula	Threshold concentration,	
		mg/liter	ppm by volume
Acrolein	$CH_2:CH\cdot CHO$	0.038	16
Allyl amine	$CH_2:CH\cdot CH_2\cdot NH_2$	0.067	28
Allyl mercaptan[a]	$CH_2:CH\cdot CH_2\cdot SH$	0.00005	0.016
Ammonia	NH_3	0.037	52
Dibutyl sulfide	$(C_4H_9)_2S$	0.0011	0.180
Ethyl mercaptan[a]	$C_2H_5\cdot SH$	0.00019	0.072
Hydrogen sulfide	H_2S	0.0011	0.770
Oxidized oils		0.0011	--
Skatole	C_9H_8NH	0.0012	0.220
Sulfur dioxide	SO_2	0.009	3.3

[a] Average value obtained with material of varying purity.

(SOURCE: AIR POLLUTION ENGINEERING MANUAL, Reference 1.)

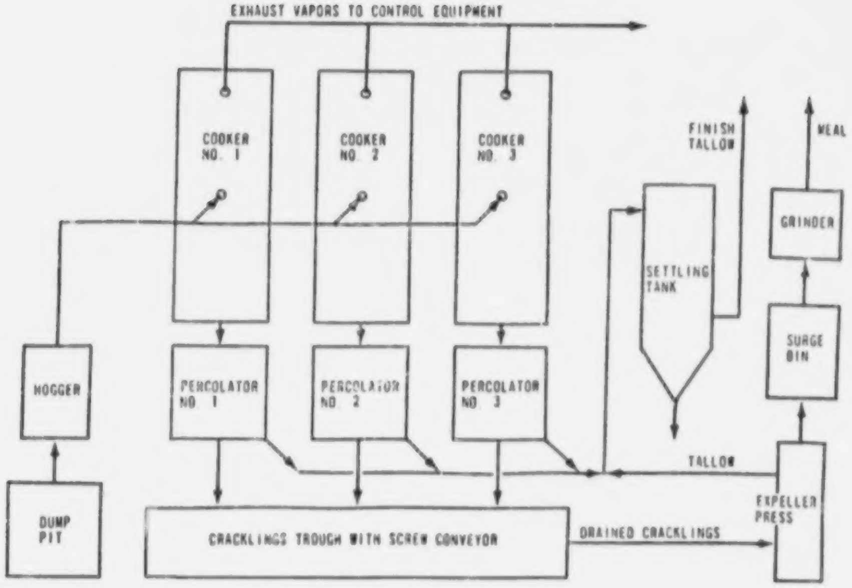
EXHAUST VAPORS TO CONTROL EQUIPMENT
COOKER NO. 1
COOKER NO. 2
COOKER NO. 3
FINISH TALLOW
MEAL
SETTLING TANK
GRINDER
SURGE BIN
HOGGER
PERCOLATOR NO. 1
PERCOLATOR NO. 2
PERCOLATOR NO. 3
TALLOW
DUMP PIT
CRACKLINGS TROUGH WITH SCREW CONVEYOR
DRAINED CRACKLINGS
EXPELLER PRESS

Figure 7.3.1. AN INTEGRATED DRY RENDERING PLANT EQUIPPED WITH BATCH COOKERS, PERCOLATORS, A CRACKLINGS PRESS, AND A TALLOW-SETTLING TANK. (SOURCE: AIR POLLUTION ENGINEERING MANUAL, Reference 1.)

1. Dry Rendering Processes

In dry process rendering, animal matter is fed into steam jacketed cookers to separate the tallow and solids by removing the moisture from the pulpy mass formed during cooking. Cookers are operated at, above, or below atmospheric pressure. Cooking under pressure is conducted at 50 psig and 300°F for 3/4 to 4 hours, depending on the type of material to be digested. Refractory stocks such as bones, hooves, hide and hair require relatively greater temperatures and pressures than organs and tissues.

After pressures are reduced the batch is further cooked at atmospheric pressure or dried to remove additional moisture and to complete separation of tallow from solids. Emission rates of odorous contaminants are a function of the rate of moisture evaporation. The maximum emissions from atmospheric cookers occur in the initial portion of the cook, while in pressure cookers the moisture evaporation rate and emissions proceeds as the temperature builds up.

When cooking is performed under vacuum, moisture is removed at comparatively lower temperatures to reduce product degradation. A precondenser, steam ejector and aftercondenser are used to produce high quality tallow, but incomplete cooking of bones, hair and other refractory materials may occur. Moisture evaporation and emission rates are a function of the rate at which the steam generated can be removed.

The composition of the material usually charged and the tallow (or grease), solids, and moisture content are shown in Table 7.3.4. The moisture content which carries the malodorous contaminants must be taken into account in the design of air pollution control equipment which should include surge tanks, condensers and hot wells.

Table 7.3.4. COMPOSITION OF TYPICAL INEDIBLE RAW MATERIALS CHARGED TO REDUCTION PROCESSES

Source	Tallow or grease, wt %	Solids, wt %	Moisture, wt %
Packing house offal and bone			
Steers	15 to 20	30 to 35	45 to 55
Cows	10 to 20	20 to 30	50 to 70
Calves	8 to 12	20 to 25	60 to 70
Sheep	25 to 35	20 to 25	45 to 55
Hogs	15 to 20	18 to 25	55 to 67
Dead stock (whole animals)			
Cattle	12	25	63
Cows	8 to 10	23	67 to 69
Sheep	22	25	53
Hogs	30	25 to 30	40 to 45
Blood	-	12 to 13	87 to 88
Feathers (from poultry houses)	-	20 to 30	70 to 80
Butcher shop scrap	37	25	38

(SOURCE: *AIR POLLUTION ENGINEERING MANUAL*, Reference 1.)

An example of a completely mechanized system using steam jacketed screw conveyors to facilitate handling in an almost completely enclosed system is shown in Figure 7.3.2. This is a continuous cooking system in which the tallow and steam are continuously tapped from the charge at various points. The charge is slurried with recycled hot tallow prior to cooking.

2. Wet Processes

In the wet process, the oldest of the animal reduction methods, live steam is introduced into a closed vessel at pressures of about 60 psig and 300°F. After separation of the materials to water, tallow and solids, the pressure is released causing some flashing of steam. Cooking continues at atmospheric pressure until the phase separation is completed. Since the resulting water contains a relatively high percentage of solids, 6 to 7 percent, further evaporation to recover these solids may be desirable. This process finds application in the rendering of whole animals but its use is being superceded by dry processing wherever possible. Vapor emission rates are lower than from dry cookers, as the bulk of the moisture is removed in the form of water.

3. Feather Cookers

Blood and feather dryers are the same type of equipment as meat and bone cookers. The charging procedures are different, however. Feathers must be charged wet and loose. The charging opening should be maintained under a slight vacuum and vented to the afterburner by-passing the condenser.

Feathers contain mostly protein and virtually no fat and are processed to produce meal only. This is accomplished by pressure in a dry cooker. Moisture is removed at ambient pressure in the cooker or

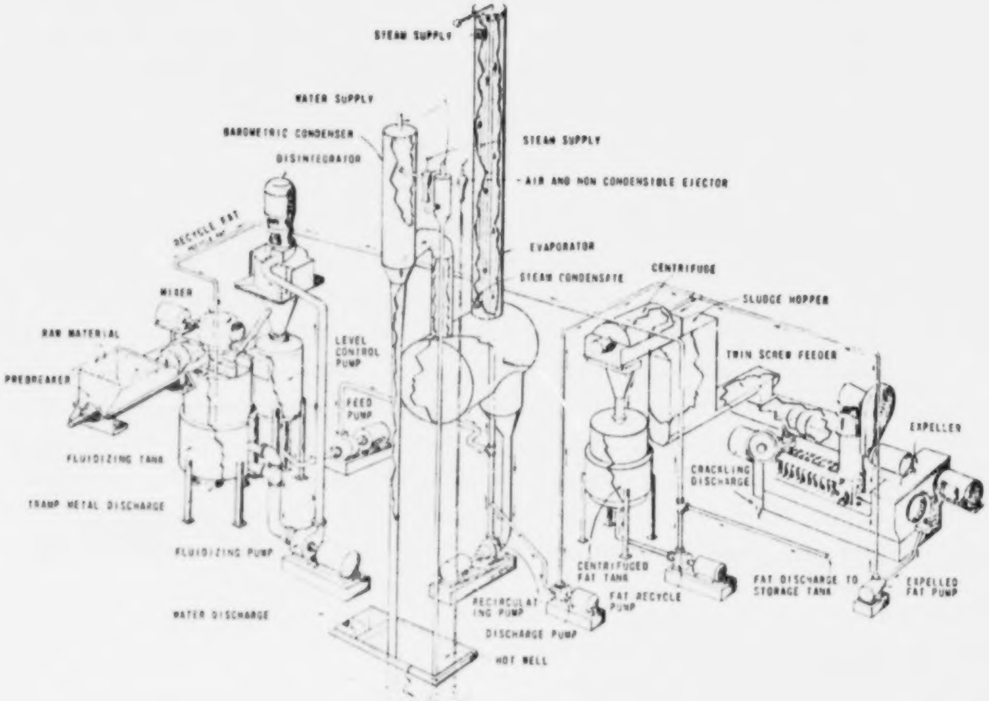
STEAM SUPPLY
WATER SUPPLY
BAROMETRIC CONDENSER
STEAM SUPPLY
DISINTEGRATOR
AIR AND NON CONDENSIBLE EJECTOR
RECYCLE FAT
EVAPORATOR
STEAM CONDENSATE
CENTRIFUGE
MIXER
SLUDGE HOPPER
RAW MATERIAL
LEVEL CONTROL PUMP
TWIN SCREW FEEDER
PREBREAKER
FEED PUMP
EXPELLER
FLUIDIZING TANK
CRACKLING DISCHARGE
TRAMP METAL DISCHARGE
FLUIDIZING PUMP
CENTRIFUGED FAT TANK
FAT DISCHARGE TO STORAGE TANK
EXPELLED FAT PUMP
RECIRCULATING PUMP
FAT RECYCLE PUMP
WATER DISCHARGE
DISCHARGE PUMP
HOT WELL

Figure 7.3.2. A CONTINUOUS, VACUUM RENDERING SYSTEM EMPLOYING TALLOW RECYCLING (CARVER-GREENFIELD PROCESS) (SOURCE: AIR POLLUTION ENGINEERING MANUAL, Reference 1.)

drier. If an air drier is used, the material is transferred to it in a wet condition. Odor concentrations are generally less and more variable than from rendering cookers and will depend on freshness of the feedstock and completeness of previous cooking.

4. Blood Drying

Blood also contains essentially no fat and is used primarily to produce meal and glue. Packing houses, where blood drying is mostly performed, usually utilize a continuous process starting at the killing room which is constructed to drain the blood to holding tanks and to the cookers. Most processing is accomplished in dry rendering cookers. Dust emissions can occur during the final portions of the drying cycle. Tubular evaporators are sometimes used to reduce initial water content to about 65% prior to transfer of material to the dry rendering cooker. Spray drying is sometimes used to produce plywood glue. In this air drying process high quantities of dust-entrained exhaust gases are produced. Blood can be concentrated in evaporators prior to spray drying. Blood drying can be very odorous if the blood has insufficiently aged before processing.

C. AIR POLLUTION CONTROLS

Controls for the reduction or elimination of odors from inedible animal matter processing are usually condensation, high temperature incineration, scrubbing, carbon adsorption, or a combination of these methods. The principal odor-causing constitutents in the steam exhausted from reduction operations are noncondensible.

The residuals from condensing the large volumes of steam should either be incinerated, preferably in a waste heat recovery device at 1200°F for no less than 0.3 seconds or adsorbed in an activated carbon filter. The use of carbon filters presents a problem of regeneration. The adsorbed material must be stripped from the carbon. This process cannot be vented directly to the atmosphere since it would have the same effect as venting the cooking steam to the atmosphere. Therefore, high temperature incineration is necessary to burn the material stripped from the carbon. This can be as costly as incineration directly after condensation.

An operating hazard for vapor collection systems occurs when the vapor exhaust line becomes plugged with solid material which can be carried over from the cooking operation (Figure 7.3.3). The system pressure will build until the material causing the blockage is set free. Unless there is a surge tank or interceptor in the system, the solid matter could carry over into the condenser or even the incinerator causing malfunctions of the odor control equipment. Therefore, a good design calls for the inclusion of an interceptor vessel in the system. Table 7.3.5 describes efficiencies of various odor removal systems.

Because of these difficulties, afterburners and condensers should be used instead of boiler fireboxes to dispose of vapors.

D. INSPECTION POINTS

Due to the severity of the odor problem, rendering plants usually are covered by public nuisance and permit system regulations. The degree of control and types of control systems used will depend on whether the objective is to materially alleviate the odor problem, or to virtually eliminate it altogether. If the objective is to alleviate the odor problem, then the use of scrubbers as the ultimate control device may be acceptable in some regions. If the objective is to eliminate the odor, then the use of an afterburner, or combination afterburner and scrubber will be mandatory.

The inspector's primary function with respect to controlled plants will be to assure that (1) hooding and ventilation systems and control systems are operated and maintained to meet intended control objectives, (2) feedstocks are rapidly processed, and (3) effective plant sanitation is practiced. Control objectives may be stated in terms of design performance standards, or odor concentration units. The latter may be defined as any odor or mixture of odors that, when dispersed in one cubic foot of odor-free-air, produces a median threshold odor detection response as measured by ASTM D 1391-57 (see Section V, Chapter 6). Table 7.3.2 shows odor concentrations and emission rates from typical process sources.

1. Environmental Observations

   Objectionable odors from rendering plants travel long distances and are readily reported by citizens. For any rendering source a complaint pattern defined by prevailing weather conditions and air flow will emerge. This pattern will serve as a baseline for "monitoring" the emissions of the plant which can be correlated with attempts to control the odors, and with operational and maintenance problems and practices at the plant. If the number of complaints increase above normal, if new complaints are identified, or odors are reported at new or more distant locations, then breakdown, negligence or other unusual conditions should be suspected. The inspector's objective will be to reduce or eliminate the incidence of complaints by the corresponding degree of odor reduction at the plant.

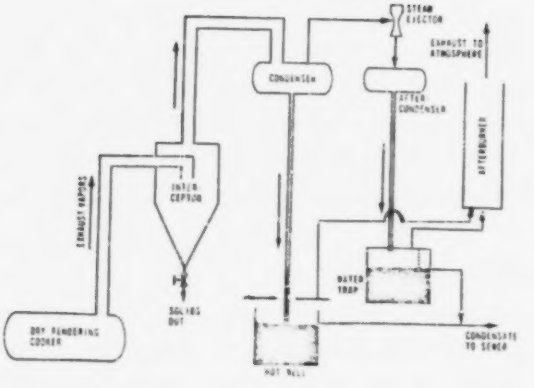
STEAM EJECTOR
EXHAUST TO ATMOSPHERE
CONDENSER
AFTER CONDENSER
AFTERBURNER
INTER CEPTOR
EXHAUST VAPORS
SOLIDS OUT
DRY RENDERING COOKER
OATED TRAP
HOT WELL
CONDENSATE TO SEWER

Figure 7.3.3. A CONDENSER-AFTERBURNER CONTROL SYSTEM WITH AN INTERCEPTOR LOCATED BETWEEN THE RENDERING COOKER AND CONDENSER (95% CONDENSIBLE) (SOURCE: AIR POLLUTION ENGINEERING MANUAL, Reference 1.)

Table 7.3.5. ODOR REMOVAL EFFICIENCIES OF CONDENSERS OR AFTERBURNERS, OR BOTH, VENTING A TYPICAL DRY RENDERING COOKER[a]

Odors from cookers		Condenser type	Condensate temperature, °F	Afterburner temperature, °F	Odors from control system		Odor removal efficiency, %
Concentration, odor units/scf	Emission rate, odor units/min				Concentration, odors units/scf	Modal emission rate, odor units/min	
50,000	25,000,000	None	--	1,200	100 to 150 (Mode 120)	90,000	99.40
		Surface	80	None	100,000 to 10 million (Mode 500,000)	12,500,000	50
		Surface	140	1,200	50 to 100 (Mode 75)	6,000	99.98
		Contact	80	None	2,000 to 20,000 (Mode 10,000)	250,000	99
		Contact	140	1,200	20 to 50 (Mode 25)	2,000	99.99

[a] Based on a hypothetical cooker that emits 500 scfm of vapor containing 5 percent noncondensable gases.

(SOURCE: AIR POLLUTION ENGINEERING MANUAL, Reference 2.)

Knowledge of the citizen response pattern and the specific operations of rendering plants is very important in tracking down the specific plant sources responsible, particularly where many rendering plants are concentrated in a given area. Procedures for tracking odors and sampling malodorous gases are described in Chapter 6, Section V.

2. Observation of the Exterior of Plant

The structure and layout of individual facilities will differ. Older plants may tend to be less efficient and more improvisational, with many of the transfer and storage operations conducted outdoors or in partially open buildings. The ground surfaces may be unpaved or cracked and hence difficult to clean and to maintain. Newer plants should include enclosable structures, washable surfaces, the use of stainless steel materials, and plant and work layout features which minimize open storage, treatment and transfer of feedstocks. All grounds should be paved with Portland cement concrete (not asphalt) for easier and more complete cleaning. Pit areas should be kept clean and covered.

Observation of the exterior of the plant will provide much information on the operation of the possible emissions from scrubbers, afterburners, and roof vents should be checked. Steam emissions may be noted, as well as misting of scrubbers. Dry visible emissions are uncommon, except for possible dusts emitted from grinding and other dry material handling procedures which do not as a rule extend beyond the plant boundaries. The plant should be observed periodically, with observations made during evenings, as well as days, to establish whether abnormal practices are occurring. The practice of using 55 gallon drums for storage of waste materials outdoors which have not been properly cleaned should be discouraged.

3. Inspection of the Interior of the Plant

As in all processes which emit odors, gases, and vapors it is important that a complete source inventory be made and that the inspector become familiar with the processes and operations that produce the most odors, so that a baseline of pollution control performance can be established. The inspector should attempt to distinguish between housekeeping and process odors and odors which may result from improperly controlled rendering equipment. The latter are generally dryer and mustier in quality than the former.

a. Interview with Plant Management

The inspector should attempt to obtain information on the following:

(1) Inventory of feedstocks. Records should be examined or estimates made of the quantity and type of feedstocks received especially with respect to bone, meat scraps, carcasses, blood, feathers, stomachs and intestines. Some feedstocks such as intestines and blood are more odorous than others. Bone and meat scraps from slaughterhouses and butcher shops tend to be less odorous. Captive rendering operations, because they are close to fresh supplies of animal wastes, usually present less of an odor problem than do independent renderers.

It is important to establish periods when feedstocks are backlogged. This can be determined from the plant operating schedule. Odors will substantially increase when backlogs remain over weekends and holiday shutdown periods, particularly in warm weather. Plants should be observed on Monday mornings.

(2) Plant Sanitation Practices. The inspector should determine if clean-up procedures are regularly practiced as part of the work schedule. It is important that work tables, drums, bins, ground surfaces, and sidings be hosed, scrubbed or otherwise cleaned and that contaminated water not be allowed to stagnate.

b. The Physical Inspection

The inspector should inspect all facilities and equipment and should observe the complete operating cycles, including material handling procedures and storage areas. Special attention should be given to sources which have high odor potentials, and the effectiveness of the operation of the control equipment. The inspector should note the following:

(1) Dead Stock Skinning Room: Relative quantities of carcasses skinned, in process of skinning, and backlogged; ventilation rates of the work area; and chemical counteractants used to relieve employee discomfort.

(2) Cookers: Type and capacities of cookers, temperatures and pressures on recording equipment, steam and vapor emissions from equipment doors during loading and unloading, length of cooking cycle, rotational speed of agitator, and addition of chemicals such as soda ash to control acidity.
The type and condition of packings and mechanical seals on doors, hatches and valves should be checked.

The rate of noncondensible emissions is related to the ventilation and moisture evaporation from the cookers. Emission rates from dry cookers are generally greater than from wet cookers. Emissions from continuous operations will tend to be lower than from batch systems. Emissions from blood and feather cookers will be comparatively lower. In the vacuum cooking procedure, the cooking cycle is adjusted to the rate of steam removal by condensation. Emission rates tend to increase with pressure cookers. Steam and vapors must be relieved through by-pass lines.

(3) Vent Lines: Design and condition; leaks in ductwork; type of condensers (contact, air-cooled, water cooled, surface); condensate temperatures; quantity of cooling water used; condition of cooling equipment; handling of condensates; use of interceptors to prevent fouling of condensers and control devices; and type of corrosion resistant materials, such as stainless steel, used in the construction of the vent lines and condensers. Where interceptors are not used the incidence of "wild blows" should be noted, particularly in dry rendering operations. Wild blows are releases of large amounts of animal matter at high velocity due to increasing line pressure. They occur whenever cooker vents become blocked.

(4) Other Sources: The inspector should note dumping of cooker contents into percolators, and collection of offgases by hoods; the type and operation of the air driers (which are usually continuous) including moisture content, temperatures and capacities; and odors from the expeller presses. Emissions from the percolator pans should be vented to the control system. The occurrence of visible emissions from the expellers should be noted.

The grinders, conveyers and handling of pressed solids should also be noted for possible dust emissions. Particles are coarse and dust emissions problems are not likely to be significant.

(5) Air Pollution Control System: The control system may consist of afterburners, condenser-afterburner combinations, scrubbers and scrubber afterburner combinations, depending on the degree of control required. In most cases any control device which is as effective as incineration at 1200°F is acceptable for use. Minimum required retention time is 0.3 seconds. A temperature and pressure recording instrument can be furnished to the inspector. Measurement of time interval should be taken from the inlet to the point where temperature is measured. Removal of exhaust moisture by use of condensers or scrubbers is required. Hot wells should be covered and vented to the afterburner. The hot well discharge should not exceed 140°F. Cyclone collectors are required on the control system if dust emissions are involved.

The inspector should determine the amount of gas available in relation to the amount required to provide the minimum required temperature. The combustion zone of the fire box and calibration of the pyrometers should be checked to assure that they have not been altered. The inspector may verify the temperature by using a pyrometer furnished to him by his agency.

Scrubber designs based on packed towers, mobile beds, meshes, woven clothes, etc. may result in clogging with resultant releases of odorous emissions. Scrubbers based on high velocity eliminators (both air and circulating water) with countercurrent spraying to achieve high saturation efficiency may be effective in reducing odor complaints.(2) Addition of soda ash solution to the scrubber water may also help to reduce odors, although this must be determined empirically in each installation. Strong oxidizing solutions such as chlorine dioxide also may be used. The inspector should note these operational details as well as the capacity of the water storage tank, the number of water changes, and the amount of makeup water added to the scrubber. Misting of the scrubber should also be noted.

Carbon adsorbers may also be as effective as afterburners, but are largely limited to drier exhaust, or to systems which cool and dry the gases prior to treatment by control equipment. Where adsorbers are used, the inspector should check temperature and moisture contents of exhausts before and after, carbon life and capacity, frequency of replacement, and the quality and quantity of carbon used. The desorbed gases must be contained or destroyed by incineration during regeneration of the carbon elements.

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IV. STEEL MILLS-FURNACES

A. DESCRIPTION OF SOURCES

The production of ferrous metals may generally be divided into (1) pig iron and steel production and (2) secondary metals or product production. Pig iron production consists of the reduction of iron ore in blast furnaces. Steel production consists of the reduction of carbon in the iron and the addition of alloys to specifications usually performed in electric steel furnaces, open hearth furnaces, and Basic Oxygen Furnaces (BOF). Secondary ferrous metal production is based on the charging of either scrap metal, pig iron (ingot) or both, and is treated in Section IX, Ferrous and Non-Ferrous Foundries.

Emissions from steel mills occur primarilly from charging, oxygen blowing and tapping operations and take the form of smoke, fumes, dust, and carbon monoxide. Particulates include, principally, iron oxide, silicon, and manganese and phosphorous oxides.

Figure 7.4.1 shows the trends in carbon steel production in the United States by furnace type indicating virtually no production from Bessemer converters after 1966 and a decline in the use of open hearth furnaces. Small gains in electric steel operations and a sharp increase in the use of basic oxygen furnaces (BOF) may be noted.(1) Production of iron and steel once concentrated in the east and midwest has expanded to the south, far west and northwestern regions of the United States.

B. PROCESS DESCRIPTION

Steel production begins with the mining of iron ore, coal and limestone. Iron ore is sintered or pellitized; limestone is crushed and graded, and coal is processed into coke. These materials are then fed to a blast furnace and are transferred in the molten state to an open hearth or basic

Process	Production of Raw Steel in 1968	
	Millions of Net Tons	Percent of Total
Open hearth furnace	66.1	50.4
Basic Oxygen furnace (BOF)	48.6	37.1
Electric furnace	16.4	12.5
Total	131.1	100

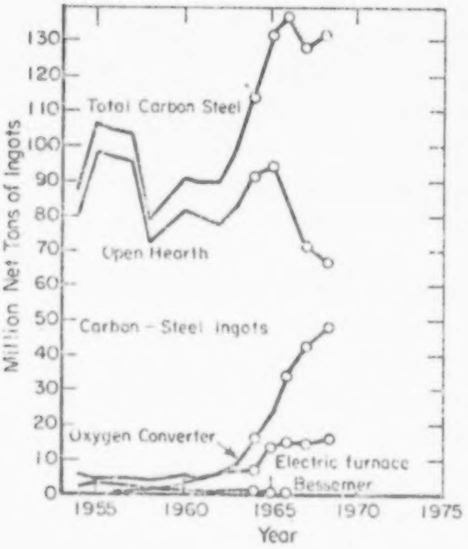

Figure 7.4.1. PRODUCTION OF CARBON RAW STEEL IN TH UNITED STATES BY VARIOUS PROCESSES (SOURCE: BATTELLE, Reference 1)

oxygen furnaces for processing into steel, or in the form of solid pigs to electric steel furnaces. Some scrap steel is used in all of the steel making processes. After alloying and reducing carbon, the steel is poured into ingots for transport to the rolling mill. The furnaces described below are utilized in steel production.

1. Blast Furnaces

Pig iron or molten iron for steel producing furnaces is produced from the reduction of iron ore FE_2O_3 (hematite) or Fe_3O_4 (magnetite) to iron in the blast furnace. Production ranges from 400 to 2400 tons/day per furnace.(2) Physically the furnace appears cylindrical but the diameter increases near the base where a Bustle Pipe or hot blast air manifold circumscribes the furnace and introduces blast air to the tuyeres as shown in Figure 7.4.2.

Blast furnace operations are continuous and are only interrupted for repairs or production cutbacks. The furnace charge or burden consists of alternate layers of iron ore, coke and limestone. At furnace startup, wood or other readily ignitable material is used to initiate combustion of the coke. Blast air, used to support combustion and force the gases through the burden, is preheated in stoves which are 28' x 100' cylinders lined with refractory brick. The refractory houses checkerwork which serves to store heat to increase the temperature of the incoming air (Figure 7.4.3).

Two or three stoves are used per blast furnace depending on the air requirements. Since air is the largest single ingredient in the production of pig iron--4 to 4 1/2 tons of air per ton of iron produced--the air handling and preheating equipment becomes very important.

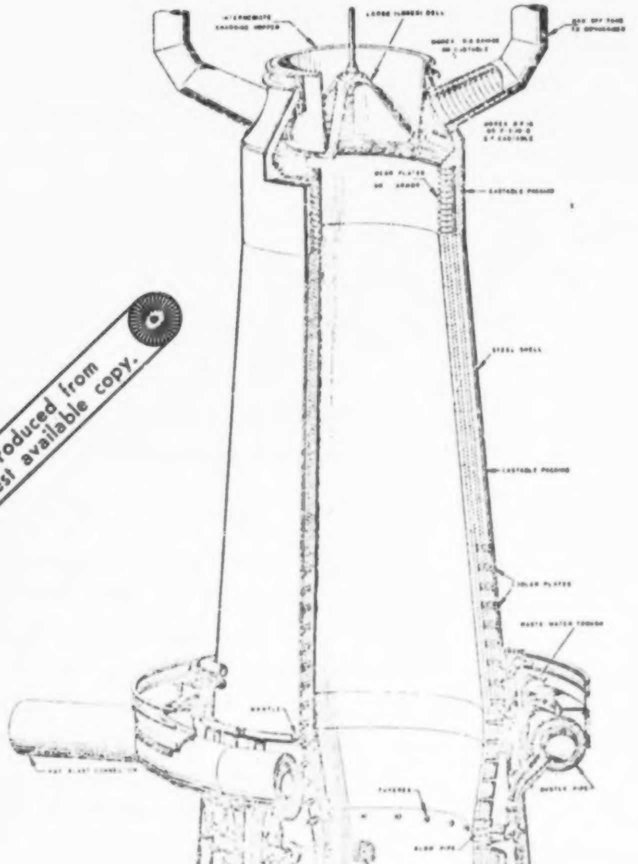
INTERMEDIATE CHARGING HOPPER
LARGE (LOWER) BELL
GAS OFF TAKE TO DOWNCOMER
WEAR PLATES OR ARMOR
CASTABLE PACKING
STEEL SHELL
CASTABLE PACKING
COOLER PLATES
WASTE WATER TROUGH
MANTLE
HOT BLAST CONNECTION
TUYERES
BUSTLE PIPE
BLOW PIPE
CINDER NOTCH
IRON NOTCH

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Figure 7.4.2. A TYPICAL BLAST FURNACE
(SOURCE: BATTELLE, Reference 1)

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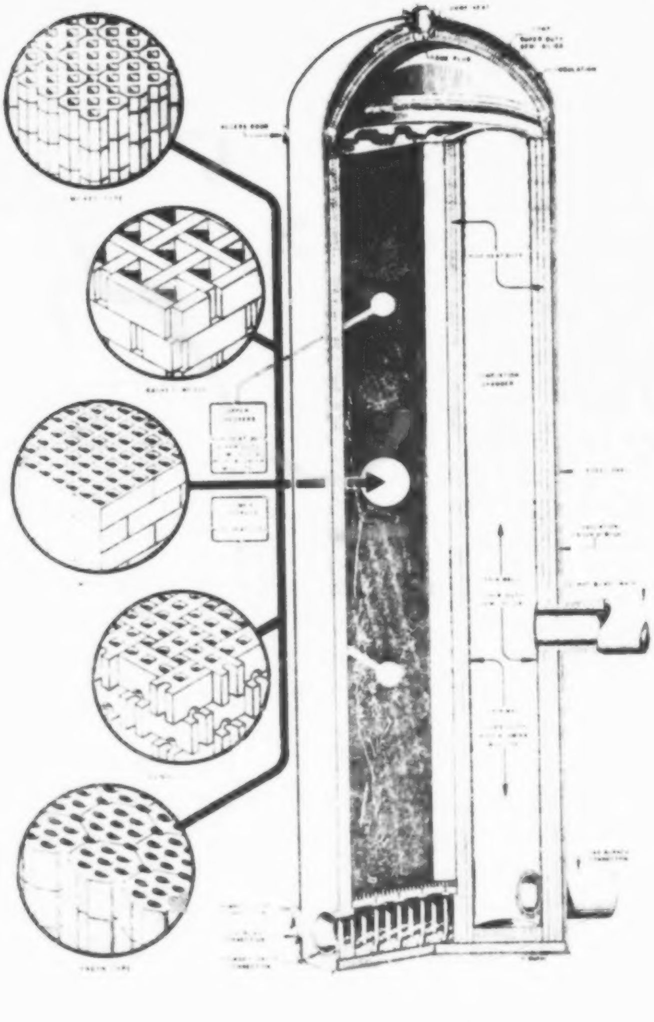

Figure 7.4.3. A TYPICAL BLAST FURNACE STOVE
(SOURCE: BATTELLE, Reference 1)

The typical solid constituents of the burden, 1.7 tons of iron ore, 0.9 ton of coke, 0.4 ton of limestone and 0.2 ton of sinter, scale and scrap are charged through the top of the furnace by a mechanical loader. As the melt progresses (the iron ore is reduced by the CO and hydrogen rising through the burden) a pool of molten iron covered by slag forms at the bottom of the furnace. Removal of metal and slag occurs every 4 to 5 hours with the slag usually removed more frequently. The molten iron runs into either a ladle or a ladle car for transport to the steel furnace while still in the molten state, completing the reduction process.

2. Electric Steel Furnaces

Electric steel furnaces are used for the refining and alloying of steel, especially stainless and specialty steels. The charge consists of steel scrap and pig iron. It is not common practice to use molten iron as a part of the charge in electric steel furnaces as it is in open hearth and BOF operations. Figure 7.4.4 shows a cutaway view of an electric furnace. Furnace capacities range from 2 to 250 tons with a melting time of 4 to 5 hours. Most electric steel furnaces used in production mills in the United States have a basic refractory lining. The few furnaces that are acid lined are used for special steels in foundries.

Physical dimensions of the furnace will, of course, vary with its capacity but the shape is usually similar to the circular cross-section and three carbon electrodes projecting from the top of the furnace, as shown in Figure 7.4.4. The production rate of the furnace is dependent upon the electrical energy supplied to the electrodes. Figure 7.4.5 shows the relationship between furnace capacity and energy input (KVA rating of transformers).

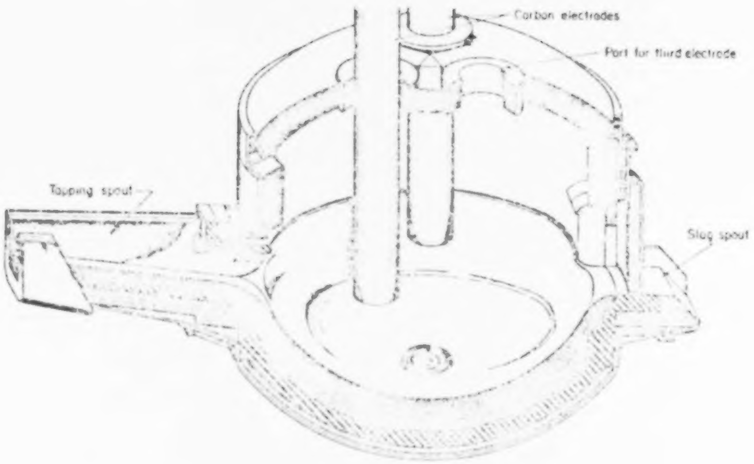
Carbon electrodes
Port for third electrode
Tapping spout
Slag spout

Figure 7.4.4. DIRECT ARC-ELECTRIC FURNACE
(SOURCE: BATTELLE, Reference 1)

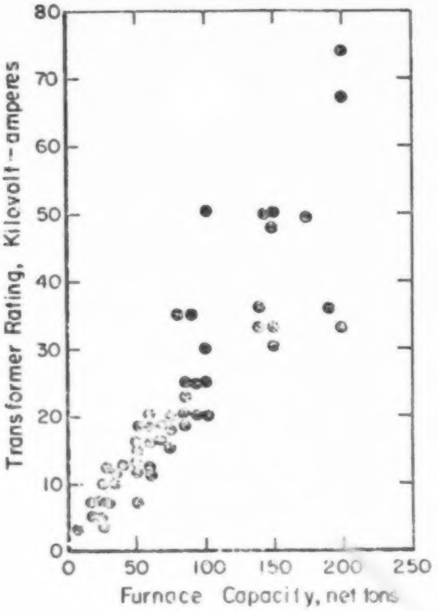

Figure 7.4.5. RELATIONSHIP BETWEEN ELECTRIC-ARC FURNACE CAPACITY AND TRANSFORMER RATING (SOURCE: BATTELLE, Reference 1)

Use of thin sheet iron scrap is generally avoided in electric furnaces since it tends to burn rather than melt. Care is also taken not to charge large quantities of dirty scrap which will cause excessive emissions by its nature. Operating procedures may include oxygen lancing to shorten the refining cycle, which causes dense emissions from the boiling of the molten metal.

3. Open Hearth Furnaces

Open hearth furnaces are the major steel producers in the United States. During the last 5 years production from the basic oxygen process has more than doubled and there is speculation that by 1990 open hearth furnaces will be completely replaced by BOF. Open hearths, however, will remain a factor in air pollution control for many years.

This method of producing steel uses either molten or solid pig iron, scrap iron and steel, iron ore and limestone and the furnace can be either acid or basic lined. The open hearth furance (Figure 7.4.6) is regenerative, i.e., uses the heat removed from the exhaust gases to preheat the combustion air in two regenerator or checkerwork sections. Each section serves alternately as the exhaust passage for the hot products of combustion and the inlet passage for combustion air and fuel (coke oven gas, natural gas, etc.). Every 15 to 20 minutes dampers are mechanically actuated to change the direction of flow of the gases, thus the term regenerative furnace.

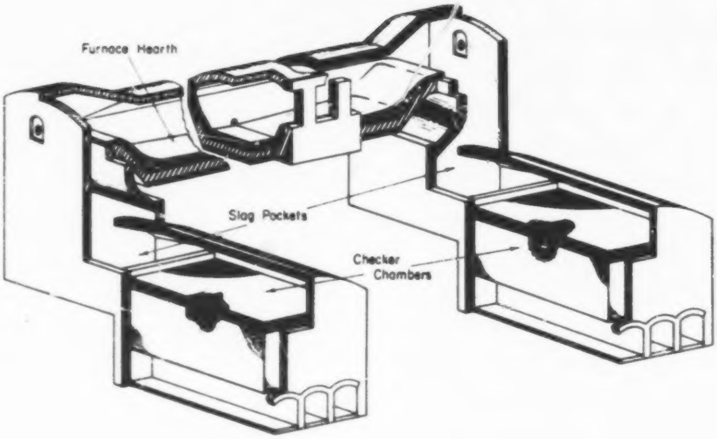
Furnace Hearth
Slag Pockets
Checker Chambers

Figure 7.4.6. CROSS-SECTION OF A BASIC OPEN-HEARTH FURNACE
(SOURCE: BATTELLE, Reference 1)

PHASE OF OPERATION	PERCENT OF TIME IN INDICATED PHASE
Tap to start (completion of one heat to start of another)	6
Charging	12
Meltdown	12
Hot-metal addition	3
Ore and lime boil	38
Working-refining	19
Tapping	2
Delay	8

Open hearth furnaces usually produce 100 to 200 tons of steel per heat which require 12 hours of furnace time without the use of oxygen, 8 hours with "light" oxygen lancing and 4 hours with "heavy" oxygen lancing. The process starts after the tap of the previous heat. This "tap to start" time is used for repairs to the hearth or other refractory material.

The next step or ore and lime boil, involves the generation of carbon monoxide from the oxidation of carbon. Gentle bubbling occurs initially followed by violent bubbling from the release of carbon dioxide from the calcining of limestone.

During the working or refining phase, the phosphorus and sulfur are reduced to specification limits, the carbon content is lowered, proper slag formation is attained and the oxygen is introduced by a lance immersed in the bath. This final step will consume 900 to 1667 standard cubic feet per minute of oxygen during the injection period totaling 600 to 1000 cubic feet per ton of metal. The heat is tapped to a ladle at approximately 3000°F and then either poured into an ingot mold or conveyed to the foundry to be poured into castings.

4. Basic Oxygen Furnace

This process for making steel is coming into increasing use in the United States due to the large reduction in the time required to produce a heat, 33 minutes vs. 8 to 12 hours(1, 2) for the open hearth.

Two principal furnace designs are the upright and the rotary (Figures 7.4.7 and 7.4.8, respectively). The process in both designs uses a hot metal charge of scrap steel and flux. The upright furnace uses a ratio of 70% hot metal to 30% scrap. Rotary furnaces can use more scrap but require longer heat time. External application of heat is not required. The hot metal and the exothermic reaction (heat release) from the oxygen and the carbon and silicon provide the necessary heat.

In the BOF process a water cooled lance blows oxygen at high velocity below the surface of the bath causing a violent reaction. The lance serves to agitate the metal, add heat to the process and to reduce, by oxidation, the carbon and other elements that are required to meet the specification of the steel being produced. Furnaces range from 75 to 325 tons per heat. There are 60 existing upright furnaces

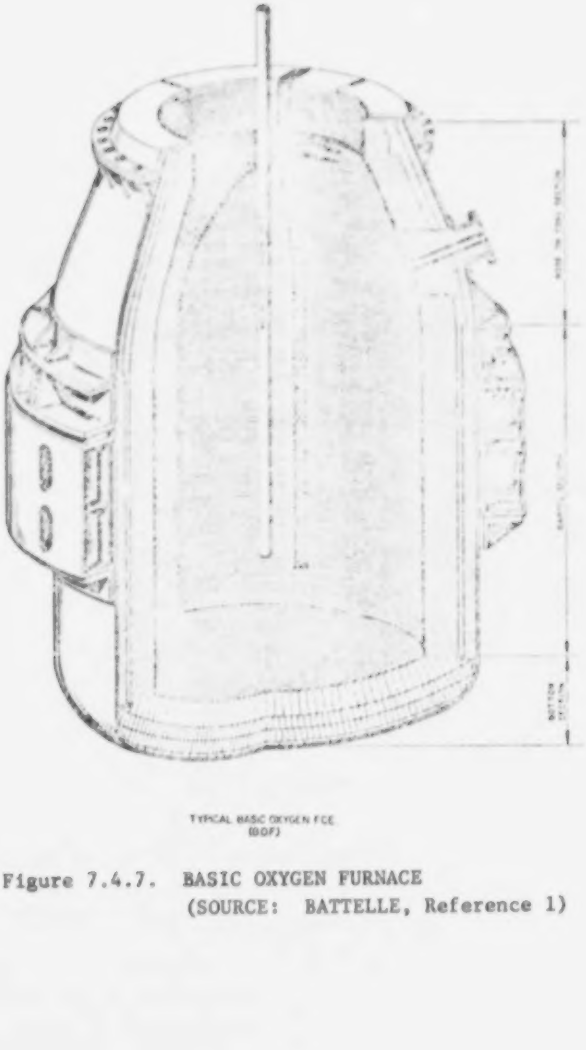
BOTTOM SECTION
TYPICAL BASIC OXYGEN FCE
(BOF)

Figure 7.4.7. BASIC OXYGEN FURNACE
(SOURCE: BATTELLE, Reference 1)

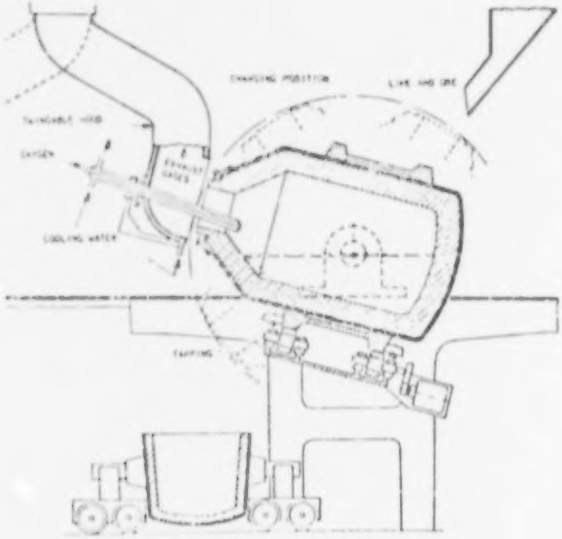
CHARGING POSITION
LIME AND ORE
SWINGABLE HOOD
OXYGEN
EXHAUST GASES
COOLING WATER
TAPPING

Figure 7.4.8. STORA-KALDO ROTARY OXYGEN CONVERTER
(SOURCE: BATTELLE, Reference 1)

in the United States(1) and 2 rotary furnaces (1969) which have a total capacity of approximately 57 million tons/year. The following represents a typical 150-ton BOF operation:(1)

Charge Scrap	1 minute
Charge Hot Metal	2 minutes
Oxygen Blow	20 minutes
Chemical Tests	5 minutes
Tapping Time	5 minutes
TOTAL TIME	33 minutes

C. EMISSIONS AND INSPECTION POINTS

Inspection points relative to emissions from iron and steel processes have certain fundamental characteristics which are the same for all of the furnace types used. These include furnace charging operations, melting, working and pouring. In addition, the maintenance of the furnaces, ductwork and dust/fume collectors must be continually inspected to determine the effectiveness of the air pollution control equipment.

1. Blast Furnaces

Most blast furnaces are charged by skip loader from the stock house for lime and ore and from the coke pile for coke. This operation will emit dust (iron ore, limestone, coke) when the skips are loaded and when the load is dumped into the top of the furnace. Since this is a continuous process some of the dust from the burden will be entrained in the exhaust gases, which have a high CO content, and will enter the dust/fume collector. On almost all blast furnaces leaks around seals and the top of the furnaces are prevalent.

The condition of the material charged to make up the burden can have a significant effect on the dust emissions. For example, the greater the ratio of sinter to ore the lower the dust loading in the effluent gas stream (top gas). As in most systems where there are high temperature or high pressure gases a by-pass or relief valve (bleeder) is required for short periods of time to relieve excess pressure caused by a buildup in the furnace.

Slips, sudden movements or shifts in the burden, create high pressures in the furnace causing the bleeders to open. Depending on the make-up of the burden, i.e., ratio of sinter and pellets to screened ore, large quantities of dust can be emitted at this time. Because slips cause the bleeder to open, the inspector should record the frequency and duration of this occurrence and the opacity of the resultant emissions.

Since the top gas is rich in CO, it is valuable as a fuel for other steel mill operations which include heating coke ovens, stoves and for waste heat boilers. This is the major economic factor in the use of dust/fume removal equipment for blast furnace top gas since the entrained dust would clog checkerwork in the coke ovens and stoves. It is anticipated that technology advances in blast furnace operations involving higher temperatures will require the top gas to be "cleaned" to 0.001 grams/SCF.(1) The gas cleaning train usually consists of a cyclone for large particle removal, a wet scrubber (which also serves as a gas conditioner) and an electrical precipitator, or venturi scrubber.

To complete the inspection of the furnace cycle the inspector should also observe the slag and iron tapping operations and record the opacity and duration of emissions.

2. Electric Steel Furnaces

Air contaminants emitted include smoke from dirty scrap and dust and fumes from melting. The operation of these furnaces requires the furnace roof to be removed during charging which poses a control problem in loading the furnaces. The Bethlehem Steel Corporation in its Los Angeles plant has abandoned conventional hooding in favor of using the entire building as a hood and collecting the emissions through the roof monitors.(3) Most electric furnaces are controlled with baghouses, although scrubbers and precipitators are also used.

During the melting period fumes are generated but pose no particular collection problem. The oxygen blow produces large quantities of brownish smoke and fumes and is probably the major source of air pollution in terms of opacity and duration of emissions and the most difficult to control with conventional hooding. The inspection report should include the quantity of oxygen used during lancing. This data is available from the operator's log.

Other observations which must be recorded include the adequacy of the dust and fume pick up system during pouring; the condition of the material charged and the charging time; a check of the air pollution control equipment to determine its operating condition and state of maintenance (see Chapter 2 for details); the condition of the entire exhaust system including the state of repair of hoods and ductwork, exhaust fan and drive belt condition; and opacity of emissions from the air pollution control equipment exhaust duct.

3. Open Hearth Furnaces

Most open hearth furnaces use hot metal directly from the blast furnace. The hot metal comprises about 60 percent of the metal charge. The remainder is scrap steel. Limestone and iron ore are added to provide a source of oxygen and to form slag. The sources of contaminants from this process include charging; products of combustion of fuel which may have a high sulfur content; iron oxide fume from oxygen blowing; and fumes from tapping and pouring operations. Oxygen lance blowing also causes large volumes of smoke and fumes. The furnace gases take a long path through the inside of the furnace, the checkerwork, and the slag pocket and frequently are passed through a waste heat boiler which serves to eliminate the larger size particles from the gas stream. The conventional control equipment applied to this process is an electrical precipitator; however, venturi scrubbers and baghouses have also been used.

The inspector should observe emissions from the scrap charged, oxygen blow, and pour that may escape the dust/fume collection train. The collection train usually includes an electrostatic precipitator.

Excessive emissions from a stack usually mean either (1) poor condition of the control equipment because of inadequate maintenance, or (2) a change in the furnace process, such as use of oxygen lancing where not previously used, or a considerable increase over the previous lancing rate.

4. Basic Oxygen Furnaces

Emissions from this process center around the oxygen blowing phase of the process. The emissions range from iron oxide from the initial burning of iron when the oxygen blow starts, to silicon, manganese and phosphorous oxides, and carbon monoxide. In this process, the hood design for collection of the effluent is critical to (1) capture of the large volumes of emission from the oxygen blow and (2) to dilute the concentration of the carbon monoxide to prevent an explosion hazard. CO combustion to CO_2 may also be considered.

Air pollution control equipment predominantly consist of water scrubbers and electrical precipitators.

The inspector can, by visual observation, determine the effectiveness of the ventilation system for the collection of emissions from this furnace. His observations during the oxygen blow and the pour can help to determine the efficiency of the hood design since most emissions from this operation are in the visible range. The inspector should also record the oxygen flow rate and total amount used.

Many of the older BOF's have undersized ventilating and collection systems because oxygen lancing rates have been increased considerably beyond what was practiced when these furnaces and control systems were designed and built. The efficiency of the control equipment, however, may call for stack testing.

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V. COKING OPERATIONS

A. DESCRIPTION OF SOURCE

The primary use for coke in the United States is in blast furnace production of iron and steel. Two types of coking processes are employed: by-product ovens, which recover volatiles, and beehive ovens which emit volatiles directly to the atmosphere.

Since 98.5% of the total U.S. coke output, as of 1967,(1) came from by-product ovens, beehive ovens are not treated in this discussion. The use of beehive ovens is economically feasible only during periods of high steel production. Increasingly stringent air pollution regulations should all but eliminate their use.

The location of coke plants is dictated by the largest user of its product, the iron and steel producing industry (See Section IV). Many steel mills conduct their own coking operations, while many coke plants are independent operations. The national distribution of coke plants by location follows very closely the distribution of major steel producing facilities although some plants are located near major coal producing areas. Approximately 60 coke manufacturing plants with an annual capacity of 60,000,000 tons per year are operated in the United States.(1)

B. PROCESS DESCRIPTIO

In coke manufacturing high rank bituminous coals with low ash and sulfur content are blended, reduced in size, and mechanically conveyed to coke ovens for carbonizing. Five basic steps are involved (see Figure 7.5.1):

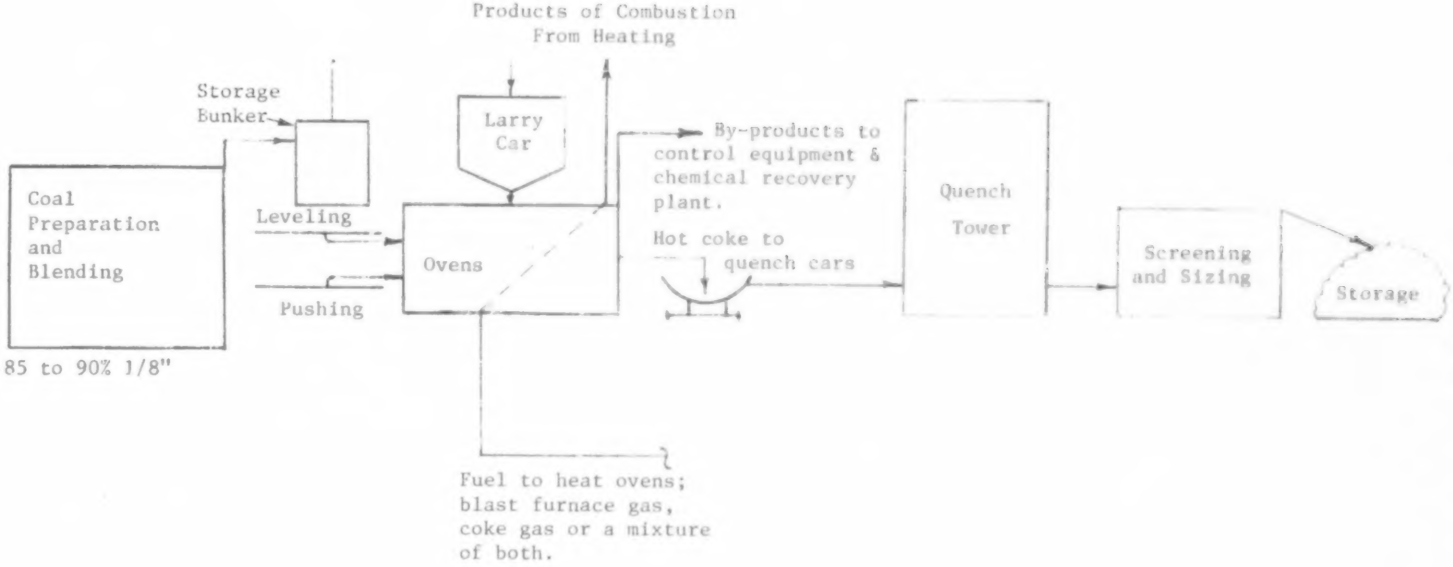

Products of Combustion From Heating
Storage Bunker
Larry Car
Coal Preparation and Blending
85 to 90% 1/8"
Leveling
Pushing
Ovens
By-products to control equipment & chemical recovery plant.
Hot coke to quench cars
Quench Tower
Screening and Sizing
Storage
Fuel to heat ovens; blast furnace gas, coke gas or a mixture of both.

Figure 7.5.1. PROCESS FLOW DIAGRAM OF COKING OPERATION

1. Coal blending and preparation to provide the coal properties required for the physical and chemical characteristics of the coke desired.
2. Carbonizing in retort ovens to drive off the volatiles from the coal.
3. A pushing sequence in which coke is removed from the ovens and pushed into gondola quench cars in an incandescent state.
4. Quenching of the coke in quench towers by applying large quantities of water.
5. Size reduction of the coke to a prescribed specification.

A sixth step, while not a processing operation, is the storage of the coke in huge piles usually at an area adjacent to the oven. This storage results in large quantities of dust being blown several miles distant from the storage piles.

The by-product coke oven is a retort which is externally heated by either blast furnace gas or coke oven gas to an inner wall temperature of from 2000°F to 2200°F. Coal is formed into coke in the retort oven in the absence of air. The oven is rectangularly shaped, 39 to 42 feet long, between 10 and 20 feet high and 14 to 20 inches wide with a 1-1/2 to 4-inch taper from push to discharge end. The oven is charged from a larry car (hopper car) into three or four ports on its top side. The ovens are arranged in banks with the larry car riding on rails on the top of the ovens.

Coal charging rates vary from 16 to 20 tons per oven per charge with a carbonizing period of 17 to 18 hours. A battery of ovens can consist of up to 100 slots (individual retort type rectangular cross-section ovens) operating as a continuous process with alternate charges and "pushes" of the distillation residue (fused coke) at about 2000°F.

The by-products generated from the coking operation are ducted to ascension pipes at either or both ends of the retort ovens and are transported under negative pressure by means of exhaust fans in collector mains to a conventional chemical treatment plant. The by-products include mixtures of organic (usually aromatic) compounds, combustible gases (carbon monoxide, hydrogen, methane, hydrogen sulfide, ammonia, and nitrogen). The organics include tarry compounds (e.g., anthracene), benzene, toluene, xylene, naththalene, phenols, and pitch. The processing system, shown in Figure 7.5.2, serves to condense, separate, absorb, distill, clarify, segment and recover the valuable substances contained in the raw gas.

The coal tar is either sold to refiners or used as fuel in the open hearth furnaces. The ammonia and pyridine materials can be removed by absorption in sulfuric acid. The ammonium sulfate which forms in the sulfuric acid solution is removed and sold to the fertilizer industry while the pyridines are sold in a crude state to chemical plants where they are further refined. The coal and gas from the coke ovens yields crude naphthalene and various light oils such as benzol, toluol, xylol, etc., which can be removed by absorption. These are stripped and refined. A prime product is the recoverable coke oven gas with a gross heating value of between 500 and 550 Btu per cubic foot. This gas is generated at about 11,000 cubic feet per ton of coal charged to the process. The gas can be used in various operations, to fire boilers or to provide a source of energy for other heating needs of the coke plant or its adjacent steel plants.(2)

Serious consideration has been given to technological changes in the production and manufacture of coke, such as pipeline charging. Any major change in operation or control is about two years away, though new pushing and quenching changes are available now. Since blast furnaces are the largest consumer of coke, the rate of growth of coke production will stabilize due to improved technology in blast furnace operations which

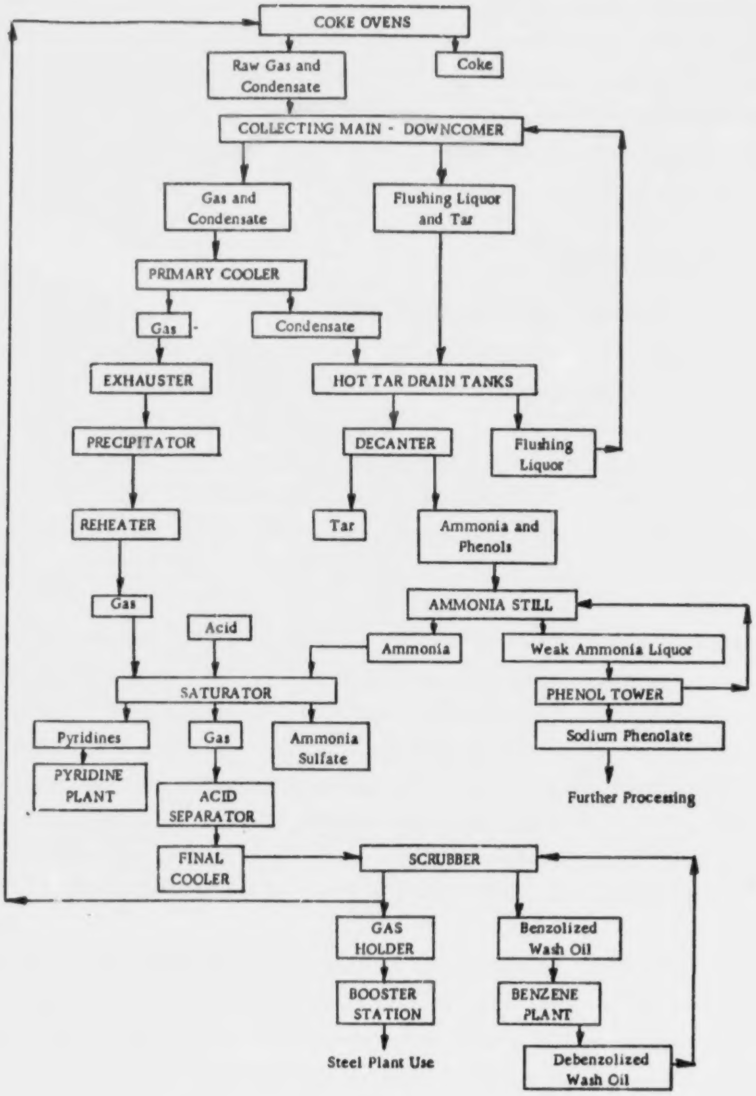

COKE OVENS
Raw Gas and Condensate
Coke
COLLECTING MAIN - DOWNCOMER
Gas and Condensate
Flushing Liquor and Tar
PRIMARY COOLER
Gas
Condensate
EXHAUSTER
HOT TAR DRAIN TANKS
PRECIPITATOR
DECANTER
Flushing Liquor
REHEATER
Tar
Ammonia and Phenols
Gas
AMMONIA STILL
Acid
Ammonia
Weak Ammonia Liquor
SATURATOR
PHENOL TOWER
Pyridines
Gas
Ammonia Sulfate
Sodium Phenolate
PYRIDINE PLANT
ACID SEPARATOR
Further Processing
FINAL COOLER
SCRUBBER
GAS HOLDER
Benzolized Wash Oil
BOOSTER STATION
BENZENE PLANT
Steel Plant Use
Debenzolized Wash Oil

Figure 7.5.2. REPRESENTATIVE BY-PRODUCT PLANT FLOW SHEET (SOURCE: BATTELLE MEMORIAL INSTITUTE, Reference 3)

will serve to reduce the quantity of coke per ton of steel produced. This source of smoke and dust is receiving very serious attention from the iron and steel industry. Extensive investigation leading to newer more self-contained methods of producing coke are required. Development toward this end is now underway in Europe but turnaround methods may be 15 years away, based on the long life of the ovens used in the United States.

C. CONTAMINANTS EMITTED

1. Coke Preparation and Oven Operations

Emissions from coking operations cover a large spectrum from smoke and particulate matter to carbon monoxide, carbon dioxide, hydrocarbons, hydrogen sulfide, and phenols occurring mainly during charging and pushing and from "leaks" around the furnace doors, charging parts, chuck doors, and any other openings. Charging of the ovens and pushing are usually the most serious air pollution control problems in coking operations.

Emission rates are estimated at approximately two pounds per hour of particulate emissions for every ton of coal processed.(1) Gaseous emission rates, coal preparation losses (directly attributable to coke operations) and airborne dust from storage piles have not been conclusively established. The latter frequently results in numerous complaints from areas adjacent to coke storage locations. The regulations most commonly violated by this process are opacity or Ringelmann number, particulate grain loading and nuisance.

In the coke preparation and blending areas the generation and emission of dust is the principal problem. The operations found here are size reduction and mechanical conveying. Dust is generated from the size reduction equipment, transfer points, loading and unloading points.

2. By-Product Processing Emissions(3)

Emissions from the primary end of the by-product processing system usually are minor in amount due to the negative pressure in the transport system. Some odor indicative of free vapor at the tar collectors and decanters or wherever the liquor runs in lines that are not fully enclosed may be noted. Ammonia and organic fumes are strong at the sumps where decanted liquor and other flush liquor is collected for recycling to the collector-mains sprays. To minimize local nuisance, the flushing liquor sewers are usually fairly well capped and covered, but there often is no sealing because these ducts become fouled with tar and other "goop." Access for stream cleaning is essential, but is not always frequently used.

Downstream of the exhausters, the detarred gas is still quite rich in ammonia, both free and in combination. The liquor decanted from the tar at primary cooling is also quite rich, and because of the moisture vaporized from wet coal this liquor exceeds the requirements of the flushing-liquor system. Both the excess liquor and the gas can be stripped of ammonia, which is recovered usually as ammonium sulfate. (America's largest coke plant is big enough to recover the ammonia on a commercial basis as anhydrous ammonia.) In the conventional sulfate process, the gas is reheated (to hold its moisture in the vapor phase) and passed through sulfuric acid where ammonium sulfate is precipitated. Ammonia vapor distilled from the surplus flushing liquor is also passed through this precipitator. The residue after distillation, known as weak liquor, may be processed further or disposed of via sewers or to the coke quench. The residue still contains ammonia plus a number of soluble organics such as phenols.

Emission to the air from the ammonia system generally is quite minor, because the ducts are closed piping for the most part, and leaks usually are promptly detected and repaired. One activity that can cause trouble in the older plants is the addition of strong sulfuric acid to the precipitator tank, an operation usually accompanied by considerable fuming of the acid.

In large coke plants, the ammonia-recovery system may be augmented by systems for recovery of phenol (carbolic acid) from the weak liquor after ammonia distillation and for recovery of pyridine bases which dissolve in the ammonium sulfate precipitator tank from the gas. In smaller coke plants, one or both of these activities may be bypassed where volume does not justify capital investment for a recovery system. Phenol and pyridine systems are closed except for tank vents, and usually have no substantial problems with regard to emission to the atmosphere.

The crude tar collected in the collector mains and in the tar decanters is augmented by minor amounts of tar precipitating at the secondary coolers or other points in the gas system. From this crude tar, pitch sludge settles to the bottom of the decanter and is mechanically raked out for disposal. Settled crude tar is sent to a separate plant for secondary processing by distillation.

Conventional tar processing yields pitch tar, creosote, and two or more weights of tar oil that may be used in roadbuilding. Crystals of naphthalene are a by-product (often discarded), and in larger plants the tar oils may be further refined to yield salable fractions.

Tars are heavily loaded with polycyclic aromatic hydrocarbons (PAH), and are generally considered hazardous. Steelmakers have recently taken steps to lead tar-processing tank vents and storage tank vents through scrubbers that absorb or destroy the fumes. The work has not met with great success yet because tars tend to condense upon and foul the equipment. When the scrubbers get fouled, they will discharge unscrubbed vent vapor.

Gas leaving the ammonia precipitation tank is still warm and contains a number of light aromatics boiling between 200 and 400 F. These light oils are condensed from vapor by cooling the gas to about ambient temperature in a final cooler. The condensate is then scrubbed with a high-boiling wash oil (derived from petroleum) to dissolve the aromatics, and the wash oil may be steam distilled to recover the principal aromatics benzene, toluene, and xylene in commercial form. The gas is now completely stripped and enters the plant fuel system. It contains 3.5 to 4.5 grains of H_2S per CF, which is emitted as SO_2 when the gas is burned.(3)

The vapors of the light oils are considered hazardous both because of toxicity and because of flammability. Nevertheless, the condensers in the distilling system and some of the process tanks are vented. The vapors issuing from these vents often pervade a large area with the sweet, almost pleasant smell characteristic of aromatic vapors.

Abnormalities (such as fire or major leakage) are rare in by-product systems because the high hazard level prompts strong preventative measures. However, in the ordinary course of pumping, straining, dewatering, and otherwise treating coke-oven by-products, leakage and vapor loss is inevitable. There may be as many as 40 pumps in the liquor and still systems; usually some of these have imperfect seals. Forced ventilation in the pumphouse is a necessity.

Identification of particulate emissions from coke-plant operations has been limited in the past, but as a result of research carried out by the integrated iron and steel industry since 1950, methods have been developed that permit the identification of particulate emissions generated in coke-plant operation. While this research has been directed primarily toward obtaining a better understanding of the coking process, and toward improvements in the properties of coke required by the advancing blast-furnace technology, it has also provided a means of identifying air-borne particulates.

D. INSPECTION POINTS

The inspector should conduct a complete inventory of the plant, including the by-product processing system. Charging of the coking ovens is probably the most important single air pollution problem with which the inspector will be concerned. The inspector should become familiar with the equipment employed and the variety of situations that may be encountered in charging operations.

In the interview of plant management, and subsequent inventory of equipment, the inspector should determine with respect to charging operations:

1. Is the suction in the header or headers employed sufficient to evacuate the emissions from the ovens with all ports and doors open? It may be necessary to charge only through two ports at a time or one port with the chuck door open.
2. Are sealed dust sleeves between hoppers and oven charging ports employed? Use of good dust sleeves should choke emissions until hoppers are emptied, greatly reducing emissions.
3. What type of feeders are employed? Use of screw feeders in place of gravity type feeders will give better coal flow control and prevent header stoppage thus lessening emissions.
4. How are charging port lids handled? Use of mechanical opening and closing devices are more positive and quick acting than manual procedures thereby reducing emissions.

5. What operating procedures are followed to reduce emissions? Sealing of ports and good mechanical maintenance are necessary factors in reducing emissions.
6. What types of mechanical controls are employed, e.g., scrubbers, baghouses, etc., and their effectiveness.

1. Dust from Material Transfer

Inspections should be made to assure that hoods covering transfer points are close fitting and provide sufficient draft to accommodate the dust emitted as the coal drops from one belt to another, is dumped into a hopper, or is transferred to other types of mechanical conveyors. Ductwork must be visually checked to determine dust losses from belts, bucket conveyors, screws, and other equipment. After all dust pickup points have been observed, the inspector should check the dust collection equipment to determine if the collection efficiency has degraded since the initial installation. Dust collectors are usually located on the roof or outside of the building housing the operation.

In the case of bag type collectors, the inspector can determine if the bags are torn by noting the opacity or density of the discharge from the bag house exhaust. He can also determine if the bags are not being properly shaken or cleaned by the reduced air intake at the hood due to back pressure in the system from insufficient cleaning of the bags. Other types of mechanical devices may be more difficult to troubleshoot; however, the two points, pickup at the dust generating source and discharge from the collector will give the inspector an overall idea of the effectiveness of the control system.

The blended and sized coal is conveyed to storage bins above the ovens and then to the oven charging device, the larry car (Figure 7.5.3). This is another transfer point which can produce a sizeable dust

Reproduced from best available copy.

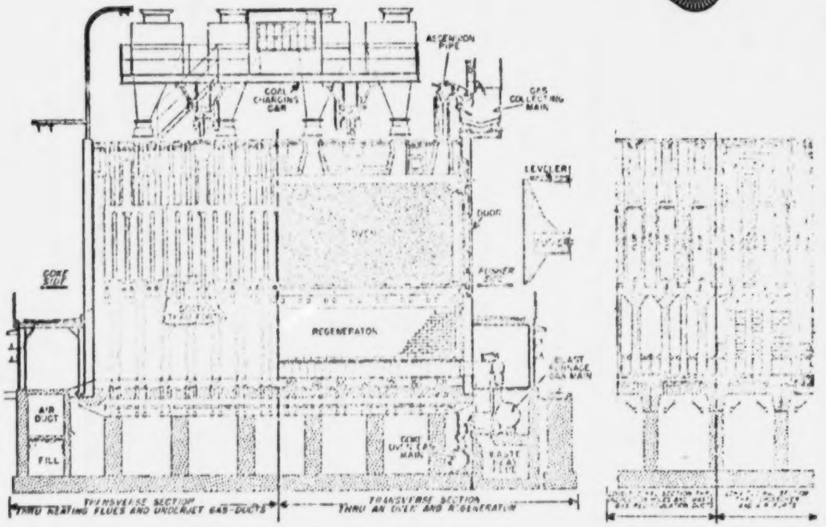

ASCENSION PIPE
COAL CHARGING CAR
GAS COLLECTING MAIN
LEVELER
DOOR
OVEN
PUSHER
COKE SIDE
REGENERATOR
BLAST FURNACE GAS MAIN
AIR DUCT
FILL
COKE OVEN GAS MAIN
WASTE HEAT FLUE
TRANSVERSE SECTION THRU HEATING FLUES AND UNDERJET GAS-DUCTS
TRANSVERSE SECTION THRU AN OVEN AND REGENERATOR

Figure 7.5.3. TRANSVERSE AND LONGITUDINAL SECTIONS THROUGH KOPPERS-BECKER UNDERJET-FIRED LOW-DIFFERENTIAL COMBINATION BY-PRODUCT COKE OVENS (SOURCE: BATTELLE MEMORIAL INSTITUTE, Reference 3).

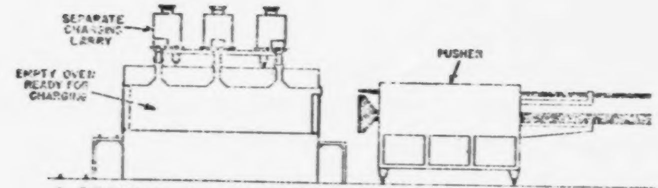
emission. An observation of this phase of the operation should provide the inspector with the information necessary to determine the effectiveness of the chute enclosure which is designed to contain dust emitted during coal transfer.

2. Charging Operations

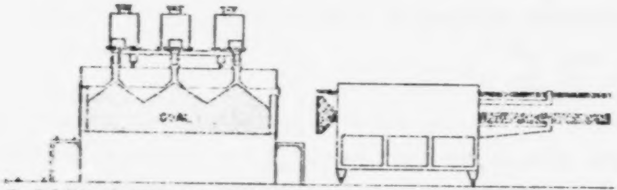
After the larry car has received its load of coal, it will proceed to the oven for charging. Ports on the top of the oven are either manually or mechanically removed allowing the larry car to be placed in a position to discharge the fresh charge into the coking oven. Highly significant smoke and dust emissions may occur at this point in the operation. Charging smoke is usually brown in color, in which case opacity regulations apply.

Consideration is being given to providing quick responding mechanical controls to open the door, insert a chute, charge the coal and replace the door lid as quickly as possible. Currently, however, most of the operations still use manual labor to open and close the loading port.

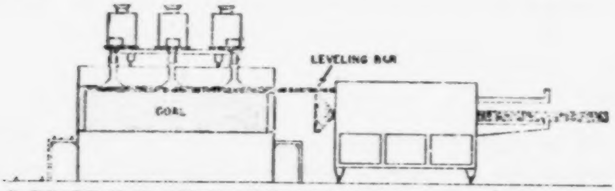
In order to reduce emissions, it is necessary that a conscientious effort be made by the workmen to replace the doors as soon as possible after the charge is dumped. During the operation a leveling bar is inserted at the pushing end of the oven to level the charge (Figure 7.5.4). This causes significant smoke and dust emissions from the push end of the oven. During the coking operation there can be emission from the slot doors and charging ports (one at each end of the oven) unless they are properly sealed. (Modern plants use mechanical seals in preference to the old luting practices for door sealing.) Also, where extensive leakage occurs from self-sealing slot oven doors, the inspector should inspect the doors to see if they are warped, investigate possible malfunctions in mechanical cleaners, such as blade defects and


SEPARATE CHARGING LARRY
EMPTY OVEN READY FOR CHARGING
PUSHER

A. THE CHARGING LARRY, WITH HOPPERS CONTAINING MEASURED AMOUNTS OF COAL, IS IN POSITION OVER CHARGING HOLES FROM WHICH COVERS HAVE BEEN REMOVED. THE PUSHER HAS BEEN MOVED INTO POSITION.



B. THE COAL FROM THE LARRY HOPPERS HAS DROPPED INTO THE OVEN CHAMBER, FORMING PEAKED PILES.


LEVELING BAR
COAL

C. THE LEVELING DOOR AT THE TOP OF THE OVEN DOOR ON THE PUSHER SIDE HAS BEEN OPENED, AND THE LEVELING BAR ON THE PUSHER HAS BEEN MOVED BACK AND FORTH ACROSS THE PEAKED COAL PILES TO LEVEL THEM. THE BAR NEXT IS WITHDRAWN FROM THE OVEN, THE LEVELING DOOR AND CHARGING HOLES ARE CLOSED, AND THE COKING OPERATION BEGINS.

Figure 7.5.4. SCHEMATIC REPRESENTATION OF CHARGING AND LEVELING OPERATIONS FOR A BY-PRODUCT COKE OVEN (SOURCE: BATTELLE MEMORIAL INSTITUTE, Reference 3.)

make sure that maintenance crews are properly trained in manual cleaning procedures. Table 7.5.1 shows the results of methods studied for charging and pushing operations.(3)

3. Condition and Operation of Oven

The condition of the oven is best indicated by emissions from doors and ports and by green pushes. For example:

1. Green pushes - maintenance needed on oven leaks and flue, oven and flue temperature, normal range (2000-2200°F for oven and 2800 to 3000°F for flue), proper cooking time, overfilling of ovens.
2. Excessive charging emissions - header maintenance required.
3. Emissions around doors - door leaks need correction.

A period of downtime when the ovens are open and being repaired is a good opportunity for the inspector to examine the internal construction of the oven. He can determine if there are cracks in the refractory wall which would allow the products of distillation to excape through the heating flue; he can see if the ascension pipes and headers have an excessive accumulation of tars which would prevent the proper seating of valves and doors, and he can see if there is a build up at the top of the oven walls which indicates poor heating which causes green coke.

An operational point which must be considered by the operator is the fact that some "green coal" (uncarbonized) remains near the door at the end of the coking period. This may account for the large volumes of smoke and dust arising from the dumped load of coke as the hot green coal hits the air and bursts into flames. Maintenance of the right flue temperature, oven tenperature, and proper coking time are operational variables which can reduce green pushes. Figure 7.5.5 illustrates the need for good control of coking time. A sharp drop in the evolution of

Table 7.5.1. SEQUENCE OF CHARGING OPERATIONS
(SOURCE: BATTELLE MEMORIAL INSTITUTE, Reference 3)

Elapsed time[(a)], minutes	Operations	Potential Emissions
0.0	Larry car is filled at blended-coal bunker and weighed. Oven doors are replaced. If lids of charging ports are removed by hand, this is done now.	Dust at bunker discharge.
2.0	Larry car moves to position over the charging ports. (Automatic lid lifters, if provided, lift lids.) Drop sleeves are lowered into ports.	Generally none.
2.7	Steam ejector in standpipe is turned on to draft oven. Coal begins to flow from hoppers on larry car and first rush of gases ignites within the oven.	Smoke emission begins slowly at ports.
2.8	Heavy rush of smoke, dust, and gas emerges around charging ports as steam formation increases oven pressures rapidly. Hoppers continue to discharge.	Brown to black smoke, with some flashes of flame.
4.0	Hoppers discharge more slowly as coal in oven rises to bases of the charging sleeves. Pusher operator goes to open the chuck door for leveling.	Continued smoke.
5.0	Coal discharge completed, drop sleeves raised. On signal from larryman, leveler bar is pushed all the way across oven, then cycled back and forth 3 to 5 feet to level the coal.	Smoke continues from ports and from the chuck door.
5.7	After 5 to 7 strokes of the leveler bar, it is withdrawn. Larryman operates lid-replacement system, or if none, he moves the larry car and crew begins to replace the lids by hand. Chuck door is closed and ejector is turned off.	Smoke continues until chuck door and port lids are well seated.
6.5	Charging completed.	Smoke via leakage only.

(a) Attainable with mainly hand operations if coordination between larryman, top crew, and pusherman is good. Charging of tall ovens or with sequenced discharge of hoppers may take longer, and some time is generally wasted between steps.

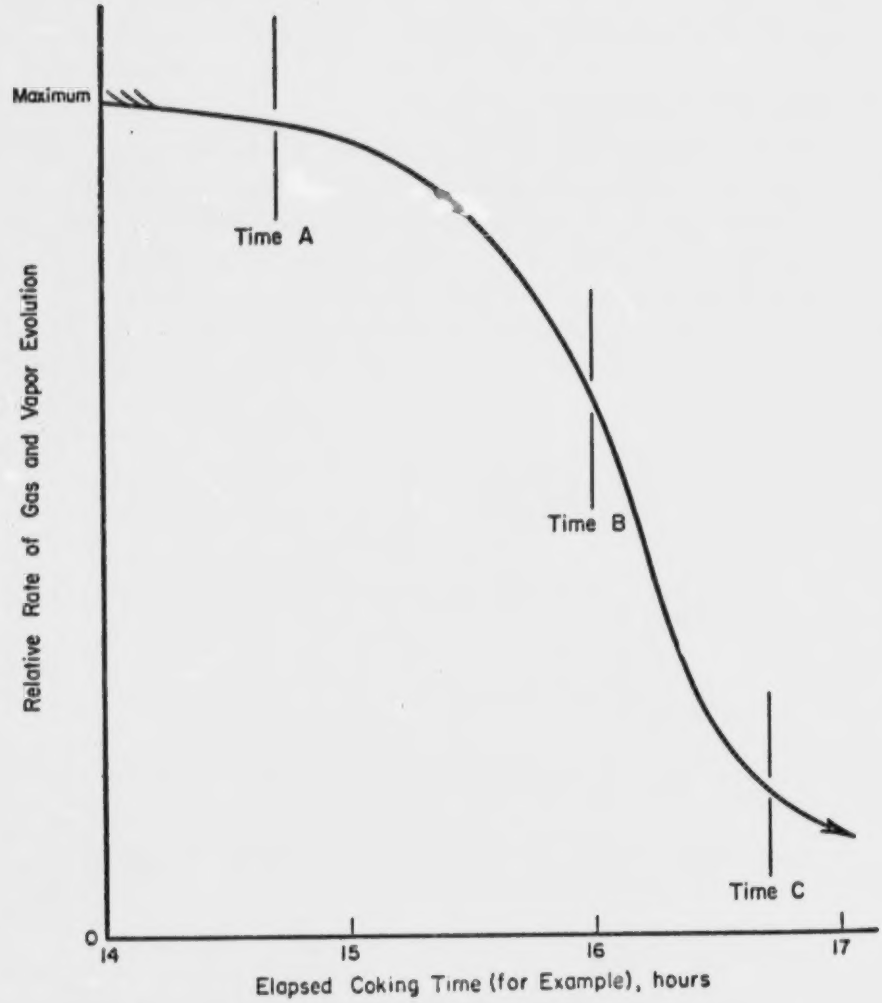
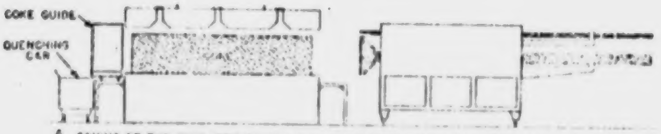


Figure 7.5.5. APPROXIMATE CURVE ILLUSTRATING THE DECLINE IN GAS AND VAPOR EVOLUTION AT THE END OF THE COKING CYCLE (SOURCE: BATTELLE MEMORIAL INSTITUTE, Reference 3.)

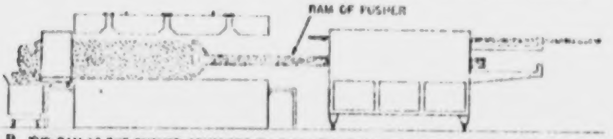
volatiles occur in the last two hours of coking indicating that early pushing will cause higher emissions.

4. Coke Transfer and Quench Operations

After the coke has been pushed (Figure 7.5.6) into the quench cars, resulting in substantial smoke and dust emissions, the cars are transferred to the quench towers where large quantities of water are used to cool the coke. The resulting emissions are covered by a water vapor plume; however, the plume may mask heavy grain loadings of dust. Droplets of corrosive materials (ammonia, phenols) may be found in the steam plumes which can cause property damage and complaints.(2)



A. COKING OF THE COAL ORIGINALLY CHARGED INTO THE OVEN HAS BEEN COMPLETED (IN ABOUT 18 HOURS) AND THE OVEN IS READY TO BE "PUSHED." THE OVEN DOORS ARE REMOVED FROM EACH END, AND THE PUSHER, COKE GUIDE AND QUENCHING CAR ARE MOVED INTO POSITION.



B. THE RAM OF THE PUSHER ADVANCES TO PUSH THE INCANDESCENT COKE OUT OF THE OVEN, THROUGH THE COKE GUIDE AND INTO THE QUENCHING CAR.

Figure 7.5.6. SCHEMATIC REPRESENTATION OF PUSHING OPERATIONS FOR A BY-PRODUCT COKE OVEN

5. Screening and Sizing

After quench, the coke is transported to the screening and sizing plant where the unit operations are not unlike those in the coal preparation operation and requires the same observation techniques.

A problem which is common to all material usually stored in the open in large piles is the dust which becomes airborne from these piles. Heavy materials handling equipment is used to move the product, agitating the pile and abrading the individual pieces of coke and creating dust which can remain airborne and be transported over long distances. This problem must be faced in all industrial activities where material with some percentage of small particles are stored in the open. Covering the piles, wetting and spraying with a plastic material are some of the methods that can be used to control the dust from storage piles.

6. Gas and Vapor Losses

The gases and vapors resulting from the distillation of the coal are ducted to the chemical recovery plant by either a single header or a dual header system. A steam injector in the ascension pipe provides added energy to convey the gases to the relatively long distance to the recovery plant. The inspector should check these headers and the ascension pipe for leaks and check any doors or ports for proper sealing or seating. Proper maintenance of these systems is essential. The inspector should make sure that the frequency of cleaning is adequate and that there is good access to all elements of the systems that must be cleaned.

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1. Control Techniques for Particulate Air Pollutants. Washington, D.C., DHEW, PHS, NAPCA, January 1969.

2. Schueneman, J. J., J. D. High, and W. E. Bye. Air Pollution Aspects of the Iron and Steel Industry. DHEW, PHS, DAP. 1963.

3. Barnes, T. M., A. D. Hoffman, and H. W. Lownie, Jr. Evaluation of Process Alternatives to Improve Control of Air Pollution from Production of Coke. Battelle Memorial Institute. Contract No. PH 22-68-65. January 31, 1970.

VI. PETROLEUM INDUSTRY

A. DESCRIPTION OF SOURCE

Operations of the petroleum industry can logically be divided into production, refining, and marketing. Production includes locating and drilling oil wells, pumping and pretreating the crude oil, recovering gas condensate, and shipping these raw products to the refinery or, in the case of gas, to commercial sales outlets. Refining, which extends to the conversion of crude to a finished salable product, includes oil refining and the manufacture of various chemicals derived from petroleum. This chemical manufacture is often referred to as the petrochemical industry. Marketing involves the distribution and the actual sale of the finished products.

As of January 1967,(1) there were 261 United States refineries capable of processing nearly 10 million barrels of crude oil daily representing an investment of roughly 11.4 billion dollars and supplying approximately 72% of the nation's fuel energy and organic chemical requirements. Energy consumption in the United States is expected to double between 1960 and 1975, with petroleum supplying a large share of the increase. A domestic demand of nearly 14 million barrels per day is projected by 1975. Nuclear power is not expected to represent a major energy contributor until the 1980's.

B. PROCESS DESCRIPTION

1. Crude Oil Production

The air contaminants emitted from crude oil production consist chiefly of the lighter saturated hydrocarbons. The main sources are process equipment and storage vessels. Hydrogen sulfide gas may be an additional contaminant in some production areas. Internal combustion equipment, mostly natural gas-fired compressors, contributes relatively negligible quantities of sulfur dioxide, nitrogen oxides, and particulate matter. Potential individual sources of air contaminants are shown in Table 7.6.1.

Contribution of air contaminants from crude-oil production varies widely with location and concentration of producing facilities. Control and pretreatment facilities such as natural gasoline plants are likely to be located in developed or highly productive areas. Control equipment for the various air pollution sources associated with crude-oil production are listed in Table 7.6.1.

2. Oil Refining

The oil refining process consists of rearranging hydrocarbon molecules obtained from crude oil to produce a variety of petroleum products, including aviation and automobile gasolines, Diesel and industrial fuel oils, domestic heating oils, lubrication oils and greases, kerosene, asphalt and coke, hydrocarbon gases, solvents, and a variety of specialty products.

The air contaminants emitted from equipment associated with oil-refining include hydrocarbons, carbon monoxide, sulfur and nitrogen compounds, malodorous materials, particulate matter, aldehydes, organic acids, and ammonia. The potential sources of these pollutants are of several types, as listed in Table 7.6.2.

Table 7.6.1. SOURCES AND CONTROL OF AIR CONTAMINANTS FROM CRUDE-OIL PRODUCTION FACILITIES (SOURCE: Air Pollution Engineering Manual, Reference 2)

Phase of operation	Source	Contaminant	Acceptable control
Well drilling, pumping	Gas venting for production rate test	Methane	Smokeless flares, wet-gas-gathering system
	Oil well pumping	Light hydrocarbon vapors	Proper maintenance
	Effluent sumps	Hydrocarbon vapors, H_2S	Replacement with closed vessels connected to vapor recovery
Storage, shipment	Gas-oil separators	Light hydrocarbon vapors	Relief to wet-gas-gathering system
	Storage tanks	Light hydrocarbon vapors, H_2S	Vapor recovery, floating roofs, pressure tanks, white paint
	Dehydrating tanks	Hydrocarbon vapors, H_2S	Closed vessels, connected to vapor recovery
	Tank truck loading	Hydrocarbon vapors	Vapor return, vapor recovery, vapor incineration, bottom loading
	Effluent sumps	Hydrocarbon vapors	Replacement with closed vessels connected to vapor recovery
	Heaters, boilers	H_2S, HC, SO_2, NO_x, particulate matter	Proper operation, use of gas fuel
Compression, absorption, dehydrating, water treating	Compressors, pumps	Hydrocarbon vapors, H_2S	Mechanical seals, packing glands vented to vapor recovery
	Scrubbers, KO pots	Hydrocarbon vapors, H_2S	Relief to flare or vapor recovery
	Absorbers, fractionators, strippers	Hydrocarbon vapors	Relief to flare or vapor recovery
	Tank truck loading	Hydrocarbon vapors, H_2S	Vapor return, vapor recovery, vapor incineration, bottom loading
	Gas odorizing	H_2S mercaptans	Positive pumping, adsorption
	Waste-effluent treating	Hydrocarbon vapors	Enclosed separators, vapor recovery or incineration
	Storage vessels	Hydrocarbon vapors, H_2S	Vapor recovery, vapor balance, floating roofs
	Heaters, boilers	Hydrocarbon, SO_2, NO_x, particulate matter	Proper operation, substitute gas as fuel

Table 7.6.2. POTENTIAL SOURCES OF EMISSIONS FROM OIL REFINING
(SOURCE: Air Pollution Engineering Manual, Reference 2)

Type of emission	Potential source
Hydrocarbons	Air blowing, barometric condensers, blind changing, blowdown systems, boilers, catalyst regenerators, compressors, cooling towers, decoking operations, flares, heaters, incinerators, loading facilities, processing vessels, pumps, sampling operations, tanks, turnaround operations, vacuum jets, waste-effluent-handling equipment
Sulfur oxides	Boilers, catalyst regenerators, decoking operations, flares, heaters, incinerators, treaters, acid sludge disposal
Carbon monoxide	Catalyst regenerators, compressor engines, coking operations, incinerators
Nitrogen oxides	Boilers, catalyst regenerators, compressor engines, flares
Particulate matter	Boilers, catalyst regenerators, coking operations, heaters, incinerators
Odors	Air blowing, barometric condensers, drains, process vessels, steam blowing, tanks, treaters, waste-effluent-handling equipment
Aldehydes	Catalyst regenerators, compressor engines
Ammonia	Catalyst regenerators

Refinery operations can be classified into four basic procedures: separation, treating, conversion, and blending.

Crude oil is initially separated into its various components or fractions, e.g., gas, gasoline, kerosine, middle distillates such as diesel fuel and fuel oil, and heavy bottoms. Since these initial fractions seldom conform to either the relative demand for each product or to its qualitative requirements, the less desirable fractions are subsequently converted to more salable products by splitting, uniting, or rearranging the original molecular structure. Separation and conversion products are subsequently treated for removal or inhibition of undesirable components. The refined base stocks may then be blended with each other and with various additives to develop the most useful products.

Individual refineries differ widely, not only as to crude oil capacity, but also as to the degree of processing sophistication employed.

The rearrangement and modification of hydrocarbons is accomplished by the following processes singly or in combination:

- Distillation--separation of hydrocarbon molecules according to boiling range and type in stills and fractional distillation columns.
- Cracking--breaking down of large complicated molecules into different compounds in catalytic cracking and hydrocracking units.
- Polymerization--joining together smaller hydrocarbon molecules to form larger molecules in polymerization units.
- Alkylation--substituting or adding an alkyl group such as methyl or ethyl.
- Hydrogenation and dehydrogenation--altering the hydrocarbon structure by adding or removing hydrogen in hydrogenation and dehydrogenation units.

- Isomerization--rearranging molecular structure of hydrocarbon molecules without changing chemical formula to develop new properties in compounds.
- Reforming--cracking of hydrocarbon to increase octane rating or to produce aromatics and paraffins from olefins in reforming. Hydroforming or Platforming units.

Virtually all of these processes are conducted catalytically at high temperatures and pressures in suitably designed equipment, or by thermal processes as in distillation and some cracking processes. Petroleum stocks are also expensively handled, treated, blended, stored and marketed.

Simple refineries may be confined to crude separation and limited treating. Intermediate refineries may add catalytic or thermal cracking, additional treating, and manufacture of such heavier products as lube oils and asphalts, waxes, and gasoline upgrading processes such as catalytic reforming, alkylation, or isomerization.

a. Separation

Crude oil is a mixture of many different hydrocarbon compounds, with also small quantities of compounds containing sulfur, oxygen, nitrogen, or other elements. Prior to any other processing, it is usually separated by distillation into fractions of differing volatility. In order of decreasing volatility (or increasing boiling point, or increasing carbon number), resulting fractions may be known as wet gas, gasoline, kerosene, fuel oil, middle distillate, lube distillate, heavy bottoms. The relative quantity of such "straight-run" products is determined by the composition of the particular crude being handled. The products may be treated and sold as finished products, or further processed and blended into more marketable fuels.

Light hydrocarbons may be further fractionated by absorption processes or other types of superfractionation. Heavy fractions may be further fractionated by distillation with steam or in vacuum. Solvent extraction and crystallization are other separation processes applied to the recovery of heavier constituents such as waxes and asphalts.

b. Treating

Sulfur, in the form of compounds such as organic sulfides, mercaptans, polysulfides and thiophenes, is the principal undesirable constituent of most crude oil. A substantial portion of the domestic crude in the United States contains over 0.5% sulfur, with some crudes exceeding 2% sulfur.

Both physical and chemical procedures are available for treating products and feedstocks for the removal of sulfur. Physical methods include electrical coalescence, filtration, absorption, and air blowing. Chemical methods include acid treatment, "sweetening" by oxidation, solvent extraction, and other means. Hydrodesulfurization processes are extensively used for treating gasolines, middle distillates, and lubricating oils. Hydrogenation converts organic sulfur compounds to hydrogen sulfide, which may be converted to elemental sulfur in sulfur recovery plants.

c. Conversion

Conversion processes are employed to increase the yield of the more desirable products such as gasoline, relative to that of less useful fractions such as middle distillates, and also to improve the quality of marketed products in terms of engine performance.

Depending on refinery operations and location, between 5 and 10% of the crude entering the refinery is consumed in processing. Refineries producing mostly light fuels and having access to low-cost supplies of natural gas consume less of the crude in this manner. Demands for unleaded gasolines having adequate antiknock performance may be expected to increase the fraction of crude that must be processed, as well as the amount of oil and gas that must be consumed to provide the energy for processing.

Conversion processes belong to three main categories, depending on whether the carbon number of the product is smaller, greater, or about the same as that of the feedstock. Processes of the first type are referred to as cracking; the main types are thermal cracking (which includes visbreaking and coking), catalytic cracking, and hydrocracking. Hydrocracking is done in the presence of a high partial pressure of hydrogen. It complements ordinary catalytic cracking and adds flexibility in meeting seasonal products demand fluctuations. In the second category, converting lighter hydrocarbons to gasoline-range products, are alkylation and polymerization. Finally, processes which improve the character of the product without major effects on the boiling range include a variety of catalytic reforming processes, as well as isomerization, cyclization, hydrogenation and dehydrogenation.

d. Blending

The relative few refinery base and intermediate stocks are blended in innumerable combinations to produce over 2,000 finished products including liquefied gases, motor and aviation fuels, lubricating oils, greases, waxes, and heating fuels. Rigid specifications as to vapor pressure, viscosity, specific gravity, sulfur content, octane number, initial boiling point, and other characteristics may be required, depending upon the intended use of the product.

The composition of gasoline, for example, is adjusted to be suitable to the climate and altitude of various marketing areas. In winter, refiners add more light hydrocarbons to increase vapor pressure and facilitate engine starting at lower temperatures. In both winter and summer, however, vapor pressure must be adjusted to minimize the problem of vapor lock. Such compromises lead to constant shifting of hydrocarbon mixtures to produce acceptable performance.

Refiners add to gasoline various chemicals such as antiknock agents (including tetraethyl lead), detergents, polymerization inhibitors, and others.

e. Types of Contaminants

Individual refineries vary greatly as to the character and quantity of emissions. Controlling factors include crude oil capacity, type of crude processed, type and complexity of the processing employed, air pollution control measures in use, and the degree of maintenance and good housekeeping procedures in force.

The major refining operations offer a guide as to the type of releases that are likely to be encountered. In crude separation the use of barometric condensers in vacuum distillation can release noncondensable hydrocarbons to the atmosphere. Regeneration of catalyst in cracking by controlled combustion can release unburned hydrocarbons, carbon monoxide, ammonia, and sulfur oxides. Catalyst handling systems can also be the source of discharge of catalyst fines. The conversion processes--alkylation, reforming, polymerization, isomerization, and their variants--are significant in that they handle volatile hydrocarbons, and leakage from such equipment as valves and pumps is of greater importance than in the processing of heavier fractions.

Air contaminants released from regeneration operations involving combustion may include catalyst dust and other particulate matter, oil mists, hydrocarbons, ammonia, sulfur oxides, chlorides, cyanides, nitrogen oxides, carbon monoxide, and aerosols. The contaminants evolved by any one type of regenerator depend on the compositions of the catalyst and reactant, and upon operating conditions.

Table 7.6.3 presents results of a survey(3) of hydrocarbon emissions from refinery sources in the Los Angeles area, interpreted in terms of emission factors related to throughput. Although these estimates may serve to indicate the possible order of magnitude of such emissions from various operations, they can be regarded as suggestive only. More recent and more detailed methods of estimating effluent rates can be found in the Air Pollution Engineering Manual.(2)

3. Marketing

An extensive network of pipelines, terminals, truck fleets, marine tankers, and storage and loading equipment must be used to deliver the finished petroleum product to the user. Hydrocarbon emissions from the distribution of products derive principally from storage vessels and filling operations. Additional hydrocarbon emissions may occur from pump seals, spillage, and effluent-water separators. Table 7.6.4 lists practical methods of minimizing these emissions from this section of the industry.

Table 7.6.3. HYDROCARBON EMISSION FACTORS FOR REFINERY SOURCES (SOURCE: Chambers, Reference 3)

SOURCE OF EMISSION	EMISSION FACTOR		
	NO CONTROL	CONTROL	UNITS(a)
Fluid catalytic cracking unit	200	10	Lbs. per 1,000 bbls. feed
Thermofor catalytic cracking unit	50	—	Lbs. per 1,000 bbls. feed
Crude oil storage tanks	500	75(b)	Lbs. per 1,000 bbls. refinery crude throughput
Petroleum distillate storage tanks	670	100(b)	Lbs. per 1,000 bbls. refinery crude throughput
Oil-water separators	400	8	Lbs. per 1,000 bbls. refinery crude throughput
Oil-water separators	300	5	Lbs. per 1,000 bbls. waste water
Vacuum jets	150	0	Lbs. per 1,000 bbls. refinery crude throughput
Loading tank trucks & trailers (avg.)	150	2	Lbs. per 1,000 bbls. loaded
Motor gasoline, 8-12 lbs. RVP	375	5	Lbs. per 1,000 bbls. loaded
Aviation gasoline, 4-8 lbs. RVP	170	2	Lbs. per 1,000 bbls. loaded
Other distillates, 1-4 lbs. RVP	90	1	Lbs. per 1,000 bbls. loaded
Pump seals	125	20(c)	Lbs. per 1,000 bbls. refinery crude throughput
Mechanical seals	—	3.2	Lbs. per seal per day
Packed seals	5.0	—	Lbs. per seal per day
Compressor seals	6	—	Lbs. per 1,000 bbls. refinery crude throughput
Compressor seals	8.5	—	Lbs. per seal per day
Valves (flow)	28	—	Lbs. per 1,000 bbls. refinery crude throughput
Valves (flow)	0.5	—	Lbs. per valve per day
Relief valves	80	5	Lbs. per 1,000 bbls. refinery crude throughput
Relief valves (on process vessels)	2.9	—	Lbs. per valve per day
Cooling towers	10	—	Lbs. per 1,000 bbls. refinery crude throughput
Cooling towers	6	—	Lbs. per 1,000,000 gals. cooling water
Treating units	8	2	Lbs. per 1,000 bbls. refinery crude throughput
Compressor exhausts	1	—	Lbs. per 1,000 cubic feet gas burned
Blowdowns, turnarounds, vessel & tank	25	5	Lbs. per 1,000 bbls. refinery crude throughput

(a) Factors are expressed in units of pounds per 1,000 barrels of refinery crude throughput where, in the opinion of the authors, the magnitude of the same source in different refineries is related approximately to their throughputs. In some cases the factors are expressed in a second unit which might prove more convenient.

(b) Floating roof controls. The factor would theoretically be zero for vapor recovery controls.

(c) Control consists of using mechanical seals in place of packed seals for light hydrocarbon service.

Table 7.6.4. SOURCES AND CONTROL OF HYDROCARBON LOSSES FROM PETROLEUM MARKETING (SOURCE: Air Pollution Engineering Manual, Reference 2)

Source	Control method
Storage vessels	Floating-roof tanks; vapor recovery; vapor disposal; vapor balance; pressure tanks; painting tanks white
Bulk-loading facilities	Vapor collection with recovery or incineration; submerged loading, bottom loading
Service station delivery	Vapor return; vapor incineration
Automotive fueling	Vapor return
Pumps	Mechanical seals; maintenance
Separators	Covers; use of fixed-roof tanks
Spills, leaks	Maintenance; proper housekeeping

C. AIR POLLUTION POTENTIAL OF PETROLEUM EQUIPMENT

Presented here are abbreviated discussions of the functions and potential emissions associated with various types of equipment used in the petroleum industry, especially in refining. For further detail, the reader is referred to the Air Pollution Engineering Manual.

1. Refining Equipment

a. Flares and Blowdown Systems

Refinery process units and equipment are periodically shut down for maintenance and repair. Losses from this source are sporadic, occuring perhaps once in six months to two years, in most cases. Hydrocarbons purged during shutdowns and startups may be manifolded to blowdown systems for recovery or flaring. Vapors can be recovered in a gas holder or compressor and discharged to the refinery fuel gas system, or they may be vented to flares or venturi burners. Good instrumentation and properly balanced steam-to-hydrocarbon ratios are needed to insure smokeless flares.

b. Pressure Relief Valves

In refinery operations, process vessels are protected from overpressure by relief valves. Corrosion or improper reseating of the valve seat results in leakage. Proper maintenance through routine inspections, or use of rupture discs, or manifolding the discharge side to vapor recovery or to a flare minimizes air contamination from this source.

c. Storage Vessels

Tanks used to store crude oil and volatile petroleum distillates are a large potential source of hydrocarbon emissions. Hydrocarbons can be discharged to the atmosphere from a storage tank as a result of diurnal temperature changes, filling operations, and volatilization. Control efficiencies of 85 to 100 percent can be realized by vapor recovery or disposal systems, floating-roof tanks, or pressure tanks.

d. Bulk-Loading Facilities

The filling of vessels used for transport of petroleum products is potentially a large source of hydrocarbon emissions. As the product is loaded, it displaces gases containing hydrocarbons to the atmosphere. An adequate method of preventing these emissions consists of collecting the vapors by enclosing the filling hatch and piping the captured vapors to recovery or disposal equipment. Submerged filling and bottom loading also reduces the amount of displaced hydrocarbon vapors.

e. Catalyst Regenerators

In various refining processes, catalysts become contaminated with coke during operation and must be regenerated or discarded. Thus, for example, in catalytic cracking, regeneration of the catalyst is a necessity and is achieved by burning off the coke under controlled combustion conditions. The resulting flue gases may contain catalyst dust, hydrocarbons, and other impurities originating in the charging stock, as well as the products of combustion.

The dust problem encountered in regeneration of moving bed type catalysts requires control by water scrubbers and cyclones, cyclones and precipitators, or high-efficiency cyclones, depending upon the type of catalyst, the process, and the regenerator conditions. Hydrocarbons, carbon monoxide, ammonia, and organic acids can be controlled effectively by incineration in carbon monoxide waste-heat boilers. The waste-heat boiler offers a secondary control feature for gases from fluid catalytic cracking units.

f. Effluent-Waste Disposal

Waste water, spent acids, spent caustic and other waste liquid materials are generated by refining operations and present disposal problems. The waste water is processed through clarification units or gravity separators. Unless adequate control measures are taken, hydrocarbons contained in the waste water are emitted to the atmosphere. Control may be achieved by venting the clarifier to vapor recovery and enclosing the separator with a floating roof or a vapor-tight cover. Spent waste materials can be recovered or hauled to an acceptable disposal site.

g. Pumps and Compressors

Pumps and compressors required to move liquids and gases in the refinery can leak product at the point of contact between the moving shaft and stationary casing. Properly maintained packing glands or mechanical seals minimize the emissions from pumps. Compressor glands can be vented to a vapor recovery system or smokeless flare.

The internal combustion engines normally used to drive the compressors are fueled by natural or refinery process gas. Even with relatively high combustion efficiency and steady load conditions, some fuel can pass through the engine unburned. Nitrogen oxides, aldehydes, and sulfur oxides can also be found in the exhaust gases.

h. Air-Blowing Operations

Venting the air used for "brightening" and agitation of petroleum products or oxidation of asphalt results in a discharge of entrained hydrocarbon vapors and mists, and malodorous compounds. Mechanical agitators that replace air agitation can reduce the volumes of these emissions. For the effluent fumes from asphalt oxidation, incineration gives effective control of the hydrocarbons and malodors.

i. Pipeline Valves and Flanges, Blind Changing, Process Drains

Liquid and vapor leaks can develop at valve stems as a result of heat, pressure, corrosion, and vibration. Regular equipment inspections followed by adequate maintenance can keep losses at a minimum. Leaks at flange connections are negligible if the connections are properly installed and maintained. Installation or removal of pipeline blinds can result in spillage of some product. A certain amount of this spilled product evaporates regardless of drainage and flushing facilities. Special pipeline blinds have, however, been developed to reduce the amount of spillage.

In refinery operation, condensate water and flushing water must be drained from process equipment. These drains also remove liquid leakage or spills and water used to cool pump glands. Modern designs provide waste-water-effluent systems with running-liquid-sealed traps and liquid-sealed and covered junction boxes. These seals keep the amount of liquid hydrocarbons exposed to the air at a minimum and thereby reduce hydrocarbon losses.

j. Cooling Towers

The large amounts of water used for cooling are conserved by recooling the water in wooden towers. Cooling is accomplished by evaporating part of this water. Any hydrocarbons that might be entrained or dissolved in the water as a result of leaking heat exchange equipment are discharged to the atmosphere. Proper design and maintenance of heat exchange equipment minimizes this loss. Process water contaminated with odorous material should not be piped to a cooling tower.

k. Vacuum Jets and Barometric Condensers

Some process equipment is operated at less than atmospheric pressure. Steam-driven vacuum jets and barometric condensers are used to obtain the desired vacuum. The lighter hydrocarbons that are not condensed are discharged to the atmosphere unless controlled. These hydrocarbons can be completely controlled by incinerating the discharge. The barometric hot well can also be enclosed and vented to a vapor disposal system. The water of the hot well should not be turned to a cooling tower.

l. Effective Air Pollution Control Measures

Control of air contaminants can be accomplished by process change, installation of control equipment, improved housekeeping, and better equipment maintenance. Some combination of these often proves the most effective solution. Table 7.6.5 indicates various methods of

Table 7.6.5. SUGGESTED CONTROL MEASURES FOR REDUCTION OF AIR CONTAMINANTS FROM PETROLEUM REFINING (SOURCE: Air Pollution Engineering Manual, Reference 2)

Source	Control method
Storage vessels	Vapor recovery systems; floating-roof tanks; pressure tanks; vapor balance; painting tanks white
Catalyst regenerators	Cyclones - precipitator - CO boiler; cyclones - water scrubber; multiple cyclones
Accumulator vents	Vapor recovery; vapor incineration
Blowdown systems	Smokeless flares - gas recovery
Pumps and compressors	Mechanical seals; vapor recovery; sealing glands by oil pressure; maintenance
Vacuum jets	Vapor incineration
Equipment valves	Inspection and maintenance
Pressure relief valves	Vapor recovery; vapor incineration; rupture discs; inspection and maintenance
Effluent-waste disposal	Enclosing separators; covering sewer boxes and using liquid seal; liquid seals on drains
Bulk-loading facilities	Vapor collection with recovery or incineration; submerged or bottom loading
Acid treating	Continuous-type agitators with mechanical mixing; replace with catalytic hydrogenation units; incinerate all vented cases; stop sludge burning
Acid sludge storage and shipping	Caustic scrubbing; incineration; vapor return system; disposal at sea
Spent-caustic handling	Incineration; scrubbing
Doctor treating	Steam strip spent doctor solution to hydrocarbon recovery before air regeneration; replace treating unit with other, less objectionable units (Merox)
Sour-water treating	Use sour-water oxidizers and gas incineration; conversion to ammonium sulfate
Mercaptan disposal	Conversion to disulfides; adding to catalytic cracking charge stock; incineration; using material in organic synthesis
Asphalt blowing	Incineration; water scrubbing (nonrecirculating type)
Shutdowns, turnarounds	Depressure and purge to vapor recovery

controlling most air pollution sources encountered in the oil refinery. These techniques are also applicable to petrochemical operations. Most of these controls result in some form of economic saving.

2. Waste-Gas Disposal Systems

Large volumes of hydrocarbon gases are produced in modern refinery and petrochemical plants. Generally, these gases are used as fuel or as raw material for further processing. In some instances, these gases have been considered waste gases and burned, producing large volumes of black smoke. With modernization of processing units, this method of waste-gas disposal, even for emergency gas releases, has become less acceptable to the industry.

Nevertheless, refineries are still faced with the problem of safe disposal of volatile liquids and gases resulting from scheduled shutdowns and sudden or unexpected upsets in process units. Emergencies that can cause the sudden venting of excessive amounts of gases and vapors include fires, compressor failures, overpressures in process vessels, line breaks, leaks, and power failures.

A system for disposal of waste gases consists of a manifolded pressure-relieving or blowdown system, and a blowdown recovery system of flares for the combustion of the excess gases, or both.

Refinery pressure-relieving systems, commonly called blowdown systems, are used primarily to ensure the safety of personnel and protect equipment in the event of emergencies. In addition, a properly designed pressure relief system permits substantial reduction of hydrocarbon emissions to the atmosphere.

The preferred method of disposing of the waste gases that cannot be recovered in a blowdown recovery system is by burning in a smokeless flare.

A blowdown or pressure-relieving system consists of relief valves, safety valves, manual bypass valves, blowdown headers, knockout vessels, and holding tanks. A blowdown recovery system also includes compressors and vapor surge vessels such as gas holders or vapor spheres.

The air pollution problem associated with the uncontrolled disposal of waste gases is the venting of large volumes of hydrocarbons and other odorous gases and aerosols. The preferred control method for excess gases and vapors is to recover them in a blowdown recovery system and, failing that, to incinerate them in an elevated-type flare. Such flares introduce the possibility of smoke and other objectionable gases such as carbon monoxide, sulfur dioxide, and nitrogen oxides. Flares have been further developed to ensure that this combustion is smokeless and in some cases nonluminous.

Smoke is the result of incomplete combustion. Smokeless combustion can be achieved by: (1) adequate heat values to obtain the minimum theoretical combustion temperatures, (2) adequate combustion air, and (3) adequate mixing of the air and fuel.

Combustion of hydrocarbons in the steam-inspirated-type elevated flare appears to be complete. Nevertheless, the results of a field test(4) on a flare unit such as this indicate that the hydrocarbon and carbon monoxide emissions from a flare can be much greater than those from a properly operated refinery boiler or furnace.

Other combustion contaminants from a flare include nitrogen oxides. The importance of these compounds depends upon the particular conditions in a particular locality.

Other air contaminants that can be emitted from flares depend upon the composition of the gases burned. The most commonly detected emission is sulfur dioxide, resulting from the combustion of various sulfur compounds (usually hydrogen sulfide) in the flared gas. Toxicity, combined with low odor threshold, make venting of hydrogen sulfide to a flare an unsuitable and sometimes dangerous method of disposal. In addition, burning relatively small amounts of hydrogen sulfide can create enough sulfur dioxide to cause crop damage or local nuisance.

Materials that tend to cause health hazards or nuisances should not be disposed of in flares. Compounds such as mercaptans or chlorinated hydrocarbons require special combustion devices with chemical treatment of the gas or its products of combustion.

3. Storage Vessels

a. Types of Storage Vessels

Storage facilities can be classified as closed-storage vessels including fixed-roof tanks, pressure tanks, floating-roof tanks and conservation tanks, and open-storage vessels including open tanks, reservoirs, pits, and ponds.

Closed-storage vessels are constructed in a variety of shapes, but most commonly as cylinders, spheres, or spheroids of steel plate. Capacities of storage vessels range from a few gallons up to 500,000 barrels.

Open tanks generally have cylindrical or rectangular shells of steel, wood, or concrete. Reservoirs, pits, ponds, and sumps are usually oval, circular, or rectangular depressions in the ground. Any roofs or covers are usually of wood with asphalt or tar protection. Capacities of the larger reservoirs may be as much as 3 million barrels.

Some pressure tanks are designed to operate at pressures as high as 200 pounds per square inch, while others may have pressure limits of only 2 pounds per square inch. Fixed-roof tanks operate within only a few ounces per square inch gauge pressure. The term "gastight," often applied to welded fixed-roof tanks, is misleading, as many such tanks have free vents open to the atmosphere. Others are equipped with "conservation" vents opening at very slight positive pressures. Also, such appurtenances as hatches, relief vents and foam mixers may fail in service, resulting in vapor leaks.

Floating roof tanks are used for storing volatile materials, to minimize fire and explosion hazards. Vaporization losses from older types of such tanks may be high. Modern designs usually incorporate compartmented dead-air spaces and vapor traps which reduce this problem.

Conservation tanks are vessels of variable volume provided by lifter-rooves, flexible diaphragms or floating blankets. Open-top tanks and reservoirs can and should be covered, but vapor losses remain appreciable if any volatilizable material is stored.

4. Loading Facilities

Gasoline and other petroleum products are distributed from the manufacturing facility to the consumer by a network of pipelines, tank vehicle routes, railroad tank cars, and ocean-going tankers, as shown in Figure 7.6.1.

As integral parts of the network, intermediate storage and loading stations receive products from refineries by either pipelines or tank vehicles. If the intermediate station is supplied by pipeline, it is called a bulk terminal, to distinguish it from the station supplied by tank vehicle, which is called a bulk plant. Retail service stations fueling motor vehicles for the public are, as a general rule, supplied by tank vehicle from bulk terminals or bulk plants. Consumer accounts, which are privately owned facilities operated, for example, to fuel vehicles of a company fleet, are supplied by tank vehicles from intermediate bulk installations or directly from refineries.

Gasoline and other petroleum products are loaded into tank trucks, trailers, or tank cars at bulk installations and refineries by means of loading racks. Bulk products are also delivered into tankers at bulk marine terminals.

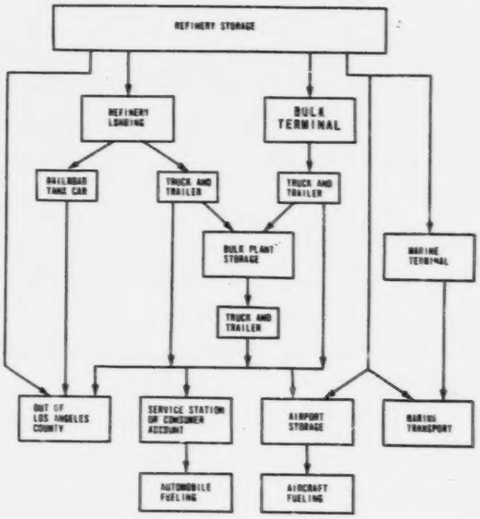

REFINERY STORAGE
REFINERY LOADING
BULK TERMINAL
RAILROAD TANK CAR
TRUCK AND TRAILER
TRUCK AND TRAILER
BULK PLANT STORAGE
MARINE TERMINAL
TRUCK AND TRAILER
OUT OF LOS ANGELES COUNTY
SERVICE STATION OR CONSUMER ACCOUNT
AIRPORT STORAGE
MARINE TRANSPORT
AUTOMOBILE FUELING
AIRCRAFT FUELING

Figure 7.6.1. REPRESENTATION OF GASOLINE DISTRIBUTION SYSTEM IN LOS ANGELES COUNTY, SHOWING FLOW OF GASOLINE FROM REFINERY TO CONSUMER
(SOURCE: Air Pollution Engineering Manual, Reference 2)

Loading racks (Figure 7.6.2) are facilities containing equipment to meter and deliver the various products into tank vehicles from storage.

Marine terminals have storage facilities for crude oil, gasoline, and other petroleum products, and facilities for loading and unloading these products to and from oceangoing tankers or barges. The loading equipment is on the dock and, in modern terminals, is similar to elevated-tank vehicle-loading facilities except for size. A pipeline manifold with flexible hoses is used for loading at older terminals. Marine installations are considerably larger and operate at much greater loading rates than inland loading installations.

When a compartment of a tank vehicle or tanker is filled through an open overhead hatch or bottom connection, the incoming liquid displaces the vapors in the compartment to the atmosphere. Ordinarily, but not always, when gasoline is loaded, the hydrocarbon concentration of the vapors is from 30 to 50 percent by volume.

The volume of vapors produced during the loading operation, as well as their composition, is greatly influenced by the type of loading or filling employed. The types in use throughout the industry may be classified under two general headings, overhead loading and bottom loading.

Overhead loading, presently the most widely used method, may be further divided into splash and submerged filling. In splash filling, the outlet of the delivery tube is above the liquid surface during all or most of the loading. In submerged filling the outlet of the delivery tube is extended to within 6 inches of the bottom and is submerged beneath the liquid during most of the loading. Splash filling generates more turbulence and therefore more hydrocarbon vapors

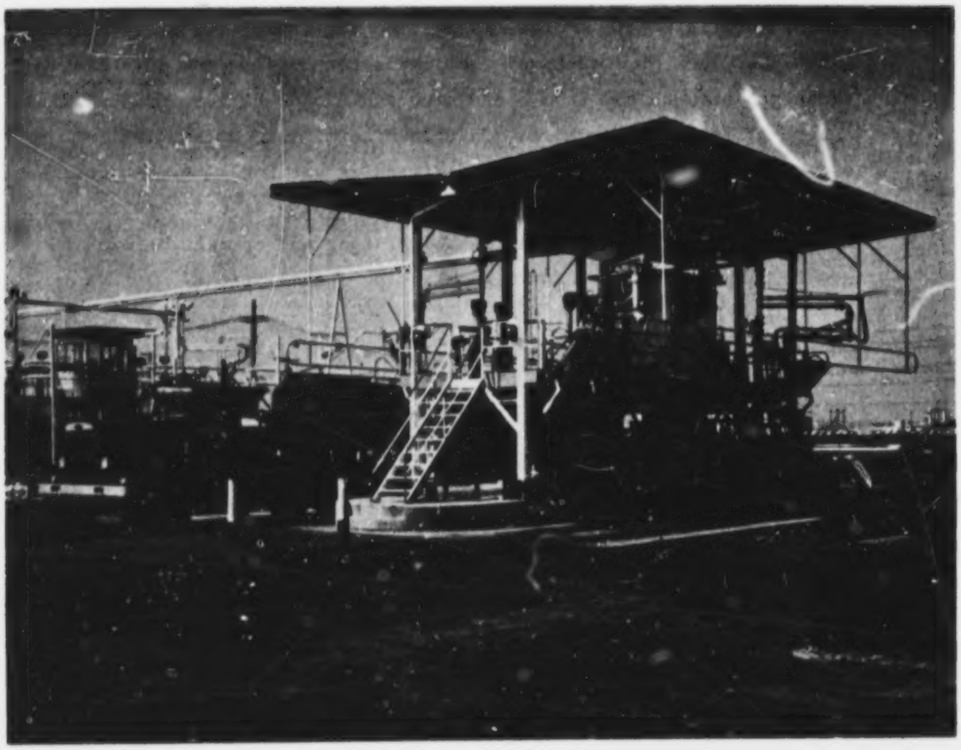


Figure 7.6.2. AN OVERHEAD-CONTROLLED LOADING RACK
(PHILLIPS PETROLEUM, LOS ANGELES, CA.)
(SOURCE: Air Pollution Engineering Manual, Reference 2)

than submerged filling does, other conditions being equal. On the basis of a typical 50 percent splash filling operation, vapor losses from the overhead filling of tank vehicles with gasoline have been determined empirically to amount to 0.1 to 0.3% of the volume loaded.(5)

Bottom loading equipment is simpler than that used for overhead loading. Loading by this method is accomplished by connecting a swing-type loading arm or hose at ground level, to a matching fitting on the underside of the tank vehicles. All the loading is submerged and under a slight pressure; thus, turbulence and resultant production of vapors are minimized.

The method employed for loading marine tankers is essentially a bottom-loading operation. Liquid is delivered to the various compartments through lines that discharge at the bottom of each compartment. The vapors displaced during loading are vented through a manifold line to the top of the ship's mast for discharge to the atmosphere.

In addition to the emissions resulting from the displacement of hydrocarbon vapors from the tank vehicles, additional emissions during loading result from evaporation of spillage, drainage, and leakage of product.

An effective system for control of vapor emissions from loading must include a device to collect the vapors at the tank vehicle hatch and a means for disposal of these vapors.

5. Catalyst Regeneration

Modern petroleum processes of cracking, reforming, hydrotreating, alkylation, polymerization, isomerization, and hydrocracking are commercially feasible because of catalysts, which accelerate specific reactions. Different catalysts vary in their effects. One might, for example, increase oxidation rates while another might change the rate of dehydrogenation or alkylation.

Contact between the catalyst and reactants is achieved in some processes by passing the reactants through fixed beds or layers of catalysts contained in a reactor vessel. Contact in other processes involves simultaneous charging of catalyst and reactants to a reactor vessel and withdrawal of used catalyst in one stream, and products and unreacted materials in another stream. The first process may be termed a fixed-bed system and the latter a moving-bed system. Moving-bed systems may be further subclassified by the type of catalyst and method of transporting it through the process. Examples are the use of vaporized charge material to fluidize powdered catalyst, as in fluid catalytic cracking units (FCC), and the use of bucket elevators, screws, airlifts, and so forth, to move the catalyst pellets or beads, as in Thermofor catalytic cracking units (TCC).

a. Types of Catalysts

Generally, the catalysts used are solids at process temperatures, though some are liquids. Cracking catalysts are usually synthetic silica-alumina compositions, including acid-treated bentonite clay, Fuller's earth, aluminum hydrosilicates, and bauxite. Bead or pelleted catalyst is used in TCC units while powdered catalyst is used in FCC units.

Catalysts employed in catalytic reforming include platinum-containing catalysts used in fixed-bed reformers, and molybdena-alumina catalysts used for fluid hydroforming. These catalysts contain less than 1% platinum supported on a base of either alumina or silica-alumina. Acid-type catalyst required for reforming processes may be provided by one of the oxides as the catalyst base. The acid may be a halogen compound added to the catalyst, or may be directly added to the reformer charge. The flow diagram of a platforming process is shown in Figure 7.6.3.

Commercial alkylation processes employ as catalysts either sulfuric acid, hydrogen fluoride, or aluminum chloride with a hydrogen chloride promoter.

Commercial polymerization catalysts consist of a thin film or phosphoric acid on fine-mesh quartz, copper pyrophosphate, or a calcined mixture of phosphoric acid.

Isomerization processes employ a noble metal, usually platinum, as the catalyst in a hydrogen atmosphere. Liquid-phase isomerization is accomplished with aluminum chloride in molten antimony chloride with a hydrogen chloride activator.

The activity of a catalyst decreases with on-stream time. The rate of decrease is related to composition of reactants contacted, throughput rate, and operating conditions. Loss of activity results from metal contamination and poisoning or from deposits that coat the catalyst surfaces and thus reduce the catalytic area available for contact with the reactants. Frequently carbon from the coking of organic materials is the main deposit. The procedure of treating the spent catalyst for removal of

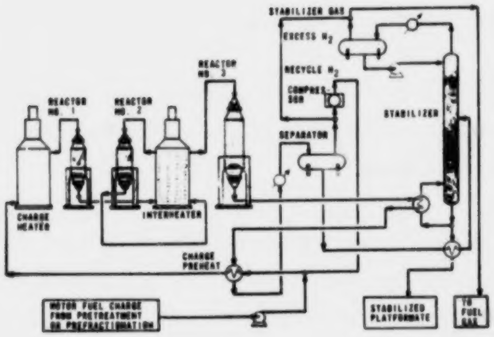

STABILIZER GAS
EXCESS H_2
RECYCLE H_2
REACTOR NO. 3
REACTOR NO. 1
REACTOR NO. 2
COMPRESSOR
STABILIZER
SEPARATOR
CHARGE HEATER
INTERHEATER
CHARGE PREHEAT
MOTOR FUEL CHARGE FROM PRETREATMENT OR PREFRACTIONATION
STABILIZED PLATFORMATE
TO FUEL GAS

Figure 7.6.3. SIMPLIFIED FLOW DIAGRAM OF PLATFORMING PROCESS
(OIL AND GAS JOURNAL, 1967)
(SOURCE: Air Pollution Engineering Manual, Reference 2)

contaminants, called catalyst regeneration, is significant from the standpoint of air pollution, since combustion is frequently the method of regeneration.

In fixed-bed systems, catalysts are regenerated periodically in the reactor or removed and returned to the manufacturer for regeneration. In moving-bed systems, catalysts are continuously removed from the reactor, regenerated in a special regenerator vessel, and returned to the reactor.

b. Regeneration Processes

Catalysts for the catalytic cracking and reforming processes are regenerated to restore activity by burning off the carbon (coke) and other deposits from the catalyst surface at controlled temperature and regeneration air rates. FCC units, all of which have continuous catalyst regeneration, have a coke burnoff rate of 5 to 10 times higher than TCC unit regenerators have. Fixed-bed reformer units and desulfurizer reactors may require regeneration only once or twice in a year.

Flue gases from catalyst regenerators for FCC units pass through cyclone separators for removal of most of the catalyst more than 10 microns in size, through a steam generator, where process steam is made, through a pressure-reducing chamber to air pollution control units, and then to the atmosphere. Final dust cleanup is accomplished by passing the effluent gases from the cyclone separators through an electric precipitator. The gases from the precipitator are introduced into a carbon monoxide boiler where the sensible heat and the heat content of the CO is used to produce steam

In a TCC unit, spent catalyst (beads) from the base of the reactor is steam purged for removal of hydrocarbons and lifted to a hopper above the regeneration kiln. Catalyst fines at this point in the process are separated from catalyst beads and are collected in a cyclone separator. Spent catalyst beads drop through a series of combustion zones, each of which contains flue gas collectors, combustion air distributors, and cooling coils. Regenerated catalyst from the bottom of the kiln is then transferred to the catalyst bin for reuse in the reactor.

The largest quantities of air pollution from catalyst-regenerating operations are experienced in fluidized cracking units. The pollutants include carbon monoxide, hydrocarbons, catalyst fines, dust, oxides of nitrogen and sulfur, ammonia, aldehydes, and cyanide. Typical losses from fluid catalytic cracking regenerators, are given by Sussman.(6)

An improvement made in FCC units in recent years is a trend toward the use of zeolite or "molecular sieve" type catalysts replacing the older amorphous (high aluminum) catalysts. As a result of using this type catalyst, less particulate emissions occur from the FCC regenerator. Also, refineries are tending to make more use of hydrogen where it is now possible to build a "hydrogen plant." TCC units are beginning to phase out.

Thermofor catalyst regeneration produces air contaminants similar to those from fluid catalyst regeneration. Quantities produced, however, are considerably less. The bead-type catalyst used in TCC units does not result in the large amount of catalyst fines that are encountered in FCC units.

Air pollution problems are not as severe from catalyst regeneration of reforming and desulfurization reactors as those from cracking units. These reactors are regenerated only once or twice a year for a period of about 24 hours. The burning of the coke and sulfur deposits yields hydrocarbons, carbon monoxide, and sulfur dioxide.

c. Air Pollution Control Equipment

Dust from fluid cracking catalyst regenerators is collected by centrifugal collectors and electrical precipitators. Carbon monoxide waste-heat boilers eliminate carbon monoxide and hydrocarbon emissions in regeneration gases. Centrifugal dust collectors are used to collect the catalyst fines from Thermofor regeneration gas.

The carbon monoxide and hydrocarbons in reforming and desulfurization catalyst regeneration gases can be efficiently incinerated by passing the regeneration gases through a heater firebox. In some installations the sulfur dioxide is scrubbed by passing the regeneration gases through a packed water or caustic tower.

6. Oil-Water Effluent Systems

Oil-water effluent systems are found in the three phases of the petroleum industry--production, refining, and marketing. The systems vary in size and complexity though their basic function remains the same, that is, to collect and separate wastes, to recover valuable oils, and to remove undesirable contaminants before discharge of the water to ocean, rivers, or channels.

In the production of crude oil, wastes such as oily brine, drilling muds, tank bottoms, and free oil are generated. Of these, the oilfield brines present the most difficult disposal problem because of the large volume encountered.

A typical collection system includes a number of small gathering lines or channels transmitting waste water to a pit, a sump, or a steel tank. A pump decants waste water from these containers to water-treating facilities. Any oil accumulating on the surface of the water is skimmed off to storage tanks.

The effluent disposal systems found in refineries are larger and more elaborate than those in the production phase. A typical modern refinery gathering system usually includes gathering lines, drain seals, junction boxes, and channels of vitrified clay or concrete for transmitting waste water from processing units to large basins or ponds used as oil-water separators. These may be earthen pits, concrete-lined basins, or steel tanks.

A drawing of a typical separator is shown in Figure 7.6.4.

Factors affecting the efficiency of separation include temperature of water, particle size, density, and amounts and characteristics of suspended matter. Stable emulsions are not affected by gravity-type separators and must be treated separately.

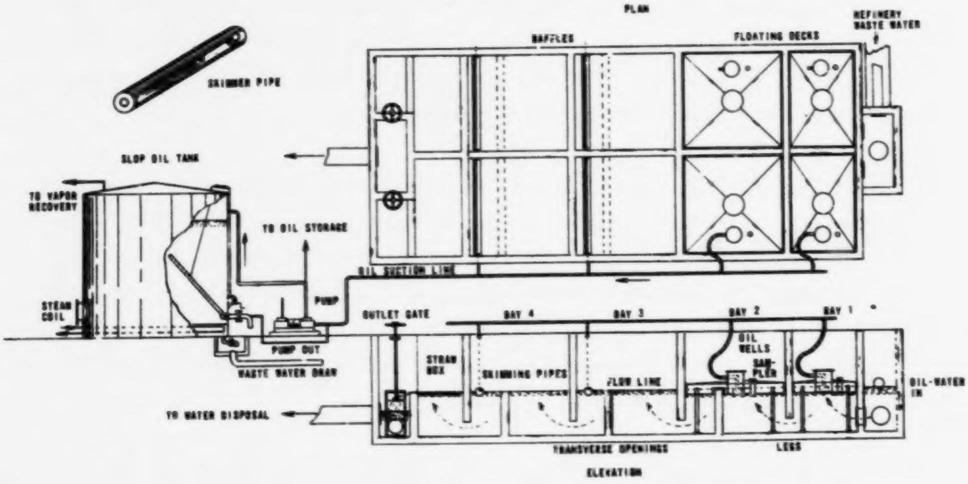

PLAN
BAFFLES
FLOATING DECKS
REFINERY WASTE WATER
SKIMMER PIPE
SLOP OIL TANK
TO VAPOR RECOVERY
TO OIL STORAGE
STEAM COIL
OIL SUCTION LINE
PUMP
PUMP OUT
WASTE WATER DRAN
OUTLET GATE
BAY 4
BAY 3
BAY 2
BAY 1
OIL WELLS
SAMPLER
STRAW BOX
SKIMMING PIPES
FLOW LINE
OIL-WATER IN
TO WATER DISPOSAL
TRANSVERSE OPENINGS
LEGS
ELEVATION

Figure 7.6.4. A MODERN OIL-WATER SEPARATOR
(SOURCE: Air Pollution Engineering Manual, Reference 2)

The oil-water separator design must provide for efficient inlet and outlet construction, sediment collection mechanisms, and oil skimmers. Reinforced concrete construction has been found most desirable for reasons of economy, maintenance, and efficiency.

The effluent water from the oil-water separator may require further treatment before final discharge to municipal sewer systems, channels, rivers, or streams. The methods include (1) filtration, (2) chemical flocculation, and (3) biological treatment.

Biological treating units such as trickling filters, activated-sludge basins, and stabilization basins are capable of reducing oil, biological oxygen demand, and phenolic content from effluent water streams. To prevent the release of air pollutants to the atmosphere, certain pieces of equipment, such as clarifiers, digesters, and filters, used in biological treatment should be covered and vented to recovery facilities or incinerated.

In the marketing and transportation phase of the industry, waste water containing oil may be discharged during the cleaning of ballast tanks of ships, tank trucks, and tank cars. Leaky valves and connections and flushing of pipelines are other sources of effluents. The methods used for treatment and disposal of these waters are similar to those used in the other phases of the industry.

a. The Air Pollution Problem

Among contaminants emitted from liquid waste streams are hydrocarbons, sulfur compounds, and other malodorous materials.

These contaminants can escape to the atmosphere from openings in the sewer system, open channels, open vessels, and open oil-water separators. The large exposed surface area of these separators requires that effective means of control be instituted to minimize hydrocarbon losses to the atmosphere from this source.

b. Asphalt from Crude Oil

Over 90% of all asphalt used in the United States is recovered from crude oil. Distillation of topped crude under a high vacuum removes oils and wax as distillate products, leaving the asphalt as a residue. Residual asphalt can be used as paving material or it can be further refined by airblowing. Asphalt is also produced as a secondary product in solvent extraction processes. The solvent, usually a light hydrocarbon such as propane or butane, is used to remove selectively a gas-oil fraction from the asphalt residue.

Economical removal of the gas-oil fraction from topped crude, leaving an asphaltic product, is occasionally feasible only by airblowing the crude residue at elevated temperatures. Excellent paving-grade asphalts are produced by this method. Another important application of airblowing is in the production of high-quality specialty asphalts for roofing, pipe coating, and similar uses. These asphalts require certain plastic properties imparted by reacting with air.

Airblowing is mainly a dehydrogenation process. Oxygen in the air combines with hydrogen in the oil molecules to form water vapor. The progressive loss of hydrogen results in polymerization or condensation of the asphalt to the desired consistency. Blowing is usually carried out batch-wise in horizontal or vertical stills equipped to blanket the charge with steam, but it may also be done continuously.

Effluents from the asphast airblowing stills include sulfur compounds, gases, odors, and aerosols. Control of effluent vapors from asphalt airblowing stills has been accomplished by scrubbing and incineration. Where removal of air pollutants is not feasible by scrubbing alone, the noncondensables must be incinerated.

7. Valves

a. Types of Valves

Valves are employed in every phase of the petroleum industry where petroleum or petroleum product is transferred by piping from one point to another. There is a great variety of valve designs, but, generally, valves may be classified by their application as flow control or pressure relief.

Flow control valves are used to regulate the flow of fluids. These valves are subject to product leakage from the valve stem as a result of the action of vibration, heat, pressure, corrosion, or improper maintenance of valve stem packing.

Pressure relief and safety valves are used to prevent excessive pressures from developing in process vessels and lines. The relief valve designates liquid flow while the safety valve designates vapor or gas flow. These valves may develop leaks because of the corrosive action of the product or because of failure of the valve to reseat properly after blowoff. Rupture discs are sometimes used in place of pressure relief valves. Their use is restricted to equipment in batch-type processes. The maintenance and operational difficulties caused by the inaccessibility of many pressure relief valves may allow leakage to become substantial.

b. The Air Pollution Problem

Quantitative data as to actual extent of emissions to the atmosphere from this leakage are somewhat limited, but available data indicate that emissions vary over a wide range. The results of a test program(7) conducted to establish the magnitude of hydrocarbon emissions from valves are presented in Table 7.6.6. In this program, valves in a group of 11 Los Angeles County refineries were surveyed.

An example of low leakage rate was observed in one refinery where over 3,500 valves handling a wide variety of products under all conditions of temperature and pressure were inspected. The average leak rate was 0.038 pound per day per valve.

Examples of high leakage rates were found in two refineries where all 440 valves inspected in gas service had an average leak rate of 1.6 pounds per day per valve, and in one other refinery where all 1,335 valves inspected in liquid service had an average leak rate of 0.32 pound per day per valve.

These examples illustrate the wide divergence from the average valve leak rate that can exist among refineries in a single area, all subject to the same obligations to restrict their emissions to the greatest possible extent. These results could not be applied, even approximately, to refineries in other areas.

Table 7.6.6. LEAKAGE OF HYDROCARBONS FROM VALVES OF REFINERIES IN LOS ANGELES COUNTY (1958) (SOURCE: Air Pollution Engineering Manual, Reference 2)

	Valves in gaseous service	Valves in liquid service	All valves
Total number of valves	31,000	101,000	132,000
Number of valves inspected	2,258	7,263	9,521
Small leaks[a]	256	768	1,024
Large leaks	118	79	197
Leaks measured	24	76	100
Total measured leakage, lb/day	218	670	888
Average leak rate--large leaks, lb/day	9.1	8.8	8.9
Total from all large leaks, lb/day	1,072	708	1,780
Estimated total from small leaks, lb/day[b]	26	77	103
Total estimated leakage from all inspected valves, lb/day	1,098	785	1,883
Average leakage per inspected valve, lb/day	0.486	0.108	0.198

[a] Small leaks are defined as leaks too small to be measured--those estimated to be less than 0.2 pound per day.

[b] Leaks too small to be measured were estimated to have an average rate of 0.1 pound per day. This is one-half the smallest measured rate.

These testing programs were also conducted on pressure relief valves in the same oil refineries. Relief valves on operational units have a slightly lower leak incidence but a much higher average leakage rate than valves on pressure storage vessels do. Moreover, dual-type valves (two single relief valves connected in parallel to ensure effective release of abnormal pressures) on pressure storage vessels have a greater leak incidence and a larger average leakage rate than single-type valves on similar service do. For valves on operational vessels, the average for all refineries was 2.9 pounds of hydrocarbons per day per valve. Average losses from specific refineries, however, varied from 0 to 9.1 pounds per day per valve. Under diverse conditions of operation and maintenance, emissions can vary greatly from one refinery to another.

8. Cooling Towers

Cooling towers are designed to cool, by air, the water used to cool industrial processes. In one style the prevailing wind is used for the required ventilation. It has become known as the natural draft or atmospheric type of cooling tower. In contrast, the mechanical draft cooling tower employs fans to move the air. Spray ponds, once used extensively for cooling, have now been abandoned in favor of towers.

The performance of an individual cooling tower is governed by the ratio of weights of air to water and the time of contact between the air and water. The required tower size is dependent upon: (1) cooling range (hot water minus cold water temperature); (2) approach (cold water minus wet bulb temperature); (3) amount of liquid to be cooled; (4) wet bulb temperature; (5) air velocity through cell; and (6) tower height.

Cooling towers used in conjunction with equipment processing hydrocarbons and their derivatives are potential sources of air pollution because of possible contamination of the water. The cooling water may be contaminated by leaks from the process side of heat-exchange equipment, direct and intentional contact with process streams, or improper process unit operation. As this water is passed over a cooling tower, volatile hydrocarbons and other materials accumulated in the water evaporate into the atmosphere. When odorous materials are contained in the water, a nuisance is easily created.

A survey(8) of the oil refineries operating in Los Angeles County indicated emissions varied from 4 to 1,500 pounds per cooling tower per day. Apparently the amount of hydrocarbon present in the water depends upon the state of maintenance of the process equipment, particularly the heat-exchange equipment, condensers, and coolers through which the water is circulated. The quantity and type of emissions should be determined by observing and testing each tower individually.

The control of hydrocarbon discharges or of release of odoriferous compounds at the cooling tower is not practical. Instead, the control must be at the point where the contaminant enters the cooling water. Hence, systems of detection of contamination in water, proper maintenance, speedy repair of leakage from process equipment and piping, and good housekeeping programs in general are necessary to minimize the air pollution occurring at the cooling tower. Water that has been used in contact with process streams, as in direct-contact or barometric-type condensers, should be eliminated from the cooling tower if this air pollution source is to be completely controlled. Greater use of fin-fan coolers can also control the emissions indirectly by reducing or eliminating the volume of cooling water to be aerated in a cooling tower.

9. Miscellaneous Sources

A number of relatively minor sources of air pollution contribute approximately 10% of the total hydrocarbon emissions to the atmosphere from refineries(7) including airblowing, blind changing, equipment turnaround, tank cleaning, use of vacuum jets, and use of compressor engine exhausts.

a. Airblowing

In certain refining operations, air is blown through heavier petroleum fractions for the purpose of removing moisture or agitating the product. The exhaust air is laden with hydrocarbon vapors and aerosols, and, if discharged directly to the atmosphere, is a source of air pollution. Results of a survey(7) show emissions of less than 1/2 ton per day. These refineries operated a total of seven airblowing units with a combined capacity of 25,000 barrels per day and a total airflow rate of 3,300 cfm. (This does not include airblowing of asphalt, which has been disucssed elsewhere in this chapter.) Emissions may be minimized by replacing the airblowing equipment with mechanical agitators and incinerating the exhaust vapors.

b. Blind Changing

Refinery operations frequently require that a pipeline be used for more than one product. To prevent leakage and contamination of a particular product, other product-connecting and product-feeding lines are customarily "blinded off." "Blinding a line" is the term commonly used for the inserting of a flat, solid plate between two flanges of a pipe connection. In opening, or breaking, the flanged connection to insert the blind, spillage of product in that portion of the pipeline can occur.

Emissions to the atmosphere from the changing of blinds can be minimized by pumping out the pipeline and then flushing the line with water before breaking the flange. In the case of highly volatile hydrocarbons, a slight vacuum may be maintained in the line. Spillage resulting from blind changing can also be minimized by use of "line" blinds which do not require a complete break of the flange connection during the changing operation.

c. Equipment Turnarounds

Periodic maintenance and repair of process equipment are essential to refinery operations. A major phase of the maintenance is the shutting down and starting up of the various units, usually called a turnaround.

In general, shutdowns are effected by first shutting off the heat supply to the unit and circulating the feed stock through the unit as it cools. Gas oil may be blended into the feedstock to prevent its solidification as the temperature drops. The cooled liquid is then pumped out to storage facilities, leaving hydrocarbon vapors in the unit. The pressure of the hydrocarbon vapors in the unit is reduced by evacuating the various items of equipment to a disposal facility such as a fuel gas system, a vapor recovery system, a flare, or in some cases, to the atmosphere. Discharging vapors to the atmosphere is undesirable from the standpoint of air pollution control. The residual hydrocarbons remaining in the unit after depressuring are purged out with steam, nitrogen, or water. Any purged gases should be discharged to disposal facilities. Condensed steam and water effluent that may be contaminated with hydrocarbons or malodorous compounds during purging should be handled by closed water-treating systems.

d. Tank Cleaning

Storage tanks in a refinery require periodic cleaning and repair. For this purpose, the contents of a tank are removed and residual vapors are purged until the tank is considered safe for entry by maintenance crews. Purging can result in the release of hydrocarbon or odorous material in the form of vapors to the atmosphere. These vapors should be discharged to a vapor recovery system or flare.

Steam cleaning of railroad tank cars used for transporting petroleum products can similarly be a source of emissions if the injected steam and entrained hydrocarbons are vented directly to the atmosphere. Some measure of control of these emissions may be effected by condensing the effluent steam and vapors. The condensate can then be separated into hydrocarbon and water phases for recovery. Noncondensable vapors should be incinerated.

e. Use of Vacuum Jets

Certain refinery processes are conducted under vacuum conditions. The most practical way to create and maintain the necessary vacuum is to use steam-actuated vacuum jets, singly or in series. Barometric condensers are often used after each vacuum jet to remove steam and condensable hydrocarbons.

The effluent stream from the last stage of the vacuum jet system should be controlled by condensing as much of the effluent as is practical and incinerating the noncondensables in an afterburner or heater firebox. Condensate should be handled by a closed treating system for recovery of hydrocarbons. The hot well that receives water from the barometric condensers may also have to be enclosed and any off gases incinerated.

f. Use of Compressor Engine Exhausts

Gas compressors are often driven by internal combustion engines that exhaust contaminants to the atmosphere. Although these engines are normally fired with natural gas and operate at essentially constant loads, some unburned fuel passes through the engine. Oxides of nitrogen are also found in the exhaust gases as a result of nitrogen fixation in the combustion cylinders.

D. INSPECTION POINTS AND PROCESS INVENTORIES

1. Initial Inspection Procedures

Due to the operational complexity of petroleum refineries, petrochemical and chemical plants and other allied activities, a degree of specialization, training, and considerable experience is required on the part of an effective refinery inspector. For such industries it is necessary to prepare technical reports of processes in terms of both written and graphic presentation to describe and determine the air pollution potentials of the process units being inspected. Special inventory forms for various types of equipment, operations, processes, or plants are helpful at inspections to ensure coverage of specific points. This procedure is required for these reasons:

- Because similar process vessels are used in various source activities and are grouped in interdependent relationships, attempts to individually itemize pieces of equipment often lead to confusion and disorientation.

- Air pollution potentials can be better determined from an inventory of functions of process vessels, than from itemization of equipment units. Process inventories may also require field surveys of product flows, throughput capacities, and emission factors.

- Refinery and chemical plant inventories thus categorize, itemize, and present data as will directly determine not only compliance with permit regulations, but also with equipment regulations.

To collect such information, a special inventory system is adapted to each refinery. In order to adequately cover each of the multiple operations of a refinery or large petrochemical plant, a system of unitization is used in which the plant area is subdivided into process units. (Those units with the greatest air pollution potentials are subsequently given added emphasis by assigning higher rates of inspection.)

Plant ownership data is recorded separately on a Plant Card. It is most important to know who the responsible officials are and how they can be quickly contacted either by a field inspector or by telephone. Where accurate field data exists in the inventory files, it is possible to make a preliminary investigation of refinery problems by telephone.

To insure that the other refineries in the area continue to receive surveillance when the inspector is busy at one refinery, the areas in which the refineries are situated are sectioned and carefully checked by patrols using a Refinery Check Sheet. On this sheet each refinery to be checked is listed. The time of observation is noted, along with any pertinent remarks concerning significant observations of each refinery. Such remarks include notations of odor, visible emissions, wind direction, etc.

The inventory records for each refinery or petrochemical plant consist of a group of file folders, each folder dealing with one of the process units. One or more process units may constitute what has been defined as the Source Activity. Hence, one inspection or inventory is made of one or more process units programmed as a unit for reinspection. At the head of each refinery file group is a numbered index of all distinct source activities within the refinery. Each number is cross-referenced to the location of the folder containing the appropriate source activity.

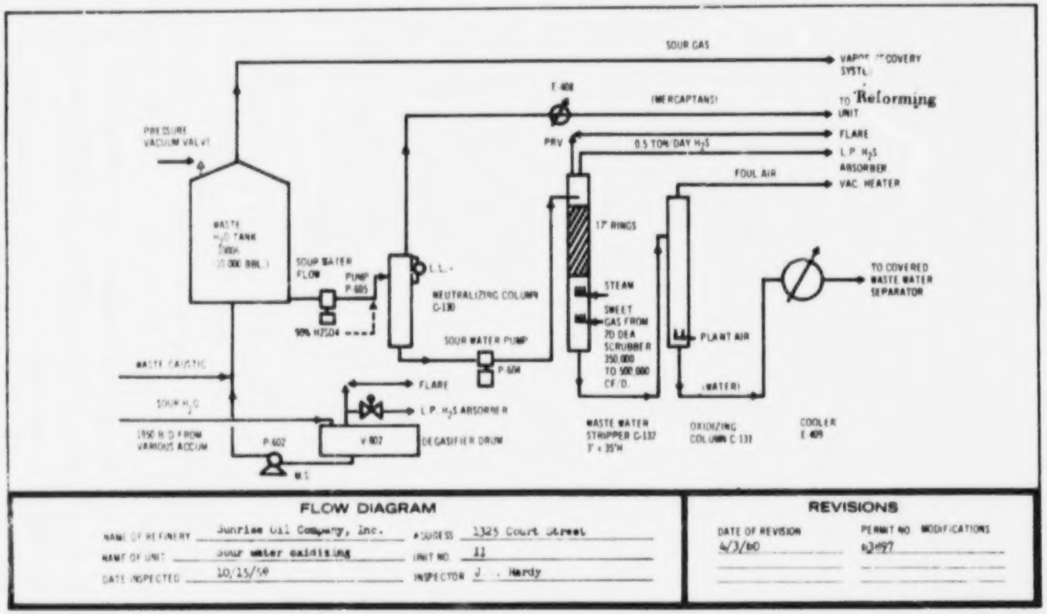
Within the folder for a given source activity, the following types of records should appear.

- A general description of the process including an analysis of its purpose and function in the order of the flow or processing sequence. Generally, the analysis traces the flow of materials from introduction through various sidestreams to final effluents.
- A list of the various pieces of equipment contained in the process unit and their function.
- The air pollution potentials of the process or the equipment should include an analysis of any important problems. This discussion should include, if possible, estimates of the contaminants emitted and their chemical designations, odor quality and intensity, opacities, or physiological effects, as well as the potential hazards of the stocks or products released should equipment failure occur.
- Throughput of volatile materials and estimates of emissions from known sources. This may be determined from results of "material balances," e.g., estimates of sulfur derivatives lost as calculated from the differences between input and final output.

- Results of any tests made of effluents or samples taken of fuels or other materials.
- A process flow chart and plot plan, which can be used for reference and verification on followup inspections and which indicate the flow rates, pressures, temperatures, etc., in process vessels and lines, where necessary, to estimate air pollution potentials and to locate points of emission.

Flow charts and plot plans are systematically drawn according to conventional engineering rules. All pertinent liquid or gas feed lines are shown and all gas or liquid effluents indicated. Overhead discharge and drainage from columns or vessels are generally shown by vectors indicating method of disposal. All features not essential to the understanding of the air pollution problem are omitted.

The flow lines are clearly labeled and vectored as to direction and content. For example: "Refinery Gas in," "To Fuel Gas System," "To Oil-Water Separator," etc. The process lines indicate whether the flow originated in, or entered at the top, side, or bottom of columns or equipment. Equipment or columns should be clearly labeled as to function unless they can be depicted by symbols (such as heat exchangers, condensers, etc., and by plant number as shown in Figure 7.6.5). It is of utmost importance in a flow diagram to clearly illustrate all sources of air pollution, including stacks, flares, pressure relief valves, etc., and to identify the problem areas and the contaminants which might be emitted. Process vessel and line operating conditions recorded on pressure and temperature gauges, manometers, continuous recorders, and relief valve pressure settings, should be indicated wherever pertinent.


SOUR GAS
VAPOR RECOVERY SYSTEM
PRESSURE VACUUM VALVE
WASTE H₂O TANK 2000A (15,000 BBL.)
SOUR WATER FLOW
PUMP P-605
90% H2SO4
L.L.
NEUTRALIZING COLUMN C-130
E-408
(MERCAPTANS)
TO Reforming UNIT
PRV
FLARE
0.5 TON/DAY H₂S
L.P. H₂S ABSORBER
FOUL AIR
VAC. HEATER
17' RINGS
STEAM
SWEET GAS FROM 70 DEA SCRUBBER 350,000 TO 500,000 CF/D.
PLANT AIR
TO COVERED WASTE WATER SEPARATOR
(WATER)
SOUR WATER PUMP
P-604
WASTE CAUSTIC
SOUR H₂O
1950 B/D FROM VARIOUS ACCUM
FLARE
L.P. H₂S ABSORBER
P-602
V-802
DEGASIFIER DRUM
M.S.
WASTE WATER STRIPPER C-132 3' x 35'H
OXIDIZING COLUMN C-131
COOLER E-409

FLOW DIAGRAM

NAME OF REFINERY Sunrise Oil Company, Inc. ADDRESS 1325 Court Street
NAME OF UNIT Sour water oxidizing UNIT NO. 11
DATE INSPECTED 10/15/50 INSPECTOR J. . Hardy

REVISIONS

DATE OF REVISION	PERMIT NO.	MODIFICATIONS
4/3/80	63497	

Figure 7.6.5. PROCESS FLOW DIAGRAM OF A SOUR WATER OXIDIZING UNIT FROM A FIELD DRAWING (PAGE 4 OF THE ACTIVITY STATUS REPORT)

A sample of an Activity Status Report covering a sour water treatment and disposal plant, and accompanying flow charts, is shown in Figures 7.6.5 and 7.6.6. To assist the inspector both in evaluating and illustrating the process, symbols may be employed in chart preparation as shown in Figure 7.6.7.

Some types of source activities are so standard that routine inventory forms are used in describing them. Such activities include bulk plants, truck loading facilities, oil-effluent water separators, tanks, natural gasoline plants, and some other types of plants operated at production facilities. Examples follow.

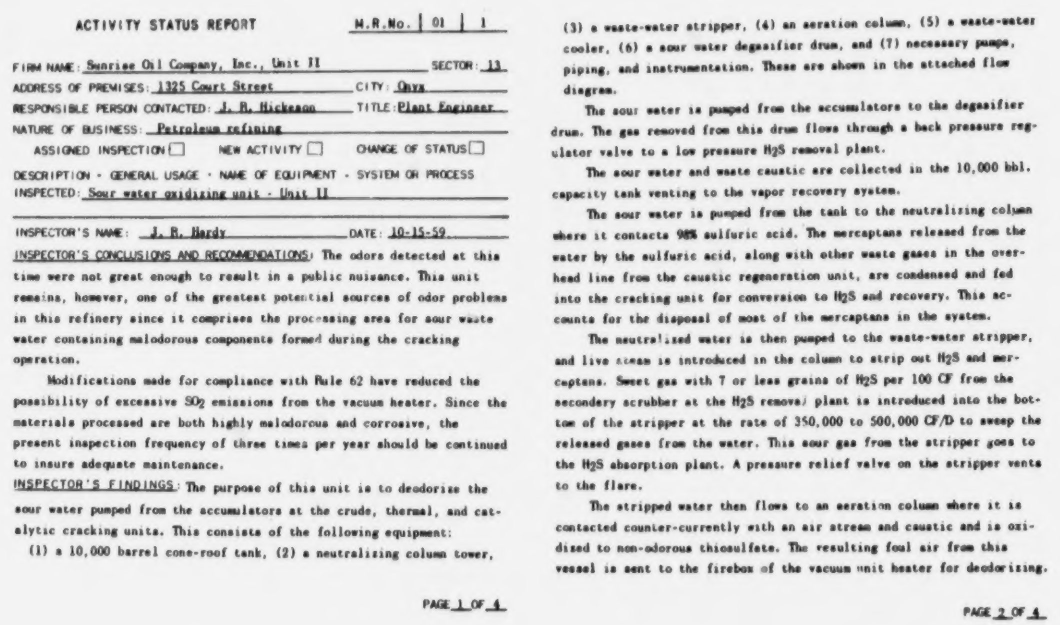
a. Bulk Plant Data

This inventory form (Figure 7.6.8) is used to record data obtained from inspection of loading racks, storage tanks, pumps, vapor controls, and associated equipment located at bulk plants. Bulk plants are used to store and distribute various petroleum products and may be found at airport facilities, distributing centers, marine terminals, etc. The form is used to emphasize compliance of equipment and operation with the applicable rules. This Bulk Plant Data Sheet, presents a master inventory for each bulk plant.

Notice (in the sample shown in Figure 7.6.8) that by increasing the number of spouts observed during the 7-8-57 reinspection the permit status changed. A Permit Request was appropriately written ("P.R.").

b. Truck Loading Inspection Data Sheet

This inspection sheet (Figure 7.6.9) is made for each truck loading facility. It lists the number of racks and spouts, the permit status of each rack, and throughputs of tank truck loading racks.



ACTIVITY STATUS REPORT M.R.No. | 01 | 1

FIRM NAME: Sunrise Oil Company, Inc., Unit II SECTOR: 13
ADDRESS OF PREMISES: 1325 Court Street CITY: Onyx
RESPONSIBLE PERSON CONTACTED: J. R. Hickeson TITLE: Plant Engineer
NATURE OF BUSINESS: Petroleum refining
ASSIGNED INSPECTION ☐ NEW ACTIVITY ☐ CHANGE OF STATUS ☐
DESCRIPTION - GENERAL USAGE - NAME OF EQUIPMENT - SYSTEM OR PROCESS
INSPECTED: Sour water oxidizing unit - Unit II

INSPECTOR'S NAME: J. R. Hardy DATE: 10-15-59

INSPECTOR'S CONCLUSIONS AND RECOMMENDATIONS: The odors detected at this time were not great enough to result in a public nuisance. This unit remains, however, one of the greatest potential sources of odor problems in this refinery since it comprises the processing area for sour waste water containing malodorous components formed during the cracking operation.

Modifications made for compliance with Rule 62 have reduced the possibility of excessive SO_2 emissions from the vacuum heater. Since the materials processed are both highly malodorous and corrosive, the present inspection frequency of three times per year should be continued to insure adequate maintenance.

INSPECTOR'S FINDINGS: The purpose of this unit is to deodorize the sour water pumped from the accumulators at the crude, thermal, and catalytic cracking units. This consists of the following equipment:

(1) a 10,000 barrel cone-roof tank, (2) a neutralizing column tower,

PAGE 1 OF 4

(3) a waste-water stripper, (4) an aeration column, (5) a waste-water cooler, (6) a sour water degasifier drum, and (7) necessary pumps, piping, and instrumentation. These are shown in the attached flow diagram.

The sour water is pumped from the accumulators to the degasifier drum. The gas removed from this drum flows through a back pressure regulator valve to a low pressure H_2S removal plant.

The sour water and waste caustic are collected in the 10,000 bbl. capacity tank venting to the vapor recovery system.

The sour water is pumped from the tank to the neutralizing column where it contacts 98% sulfuric acid. The mercaptans released from the water by the sulfuric acid, along with other waste gases in the overhead line from the caustic regeneration unit, are condensed and fed into the cracking unit for conversion to H_2S and recovery. This accounts for the disposal of most of the mercaptans in the system.

The neutralized water is then pumped to the waste-water stripper, and live steam is introduced in the column to strip out H_2S and mercaptans. Sweet gas with 7 or less grains of H_2S per 100 CF from the secondery scrubber at the H_2S removal plant is introduced into the bottom of the stripper at the rate of 350,000 to 500,000 CF/D to sweep the released gases from the water. This sour gas from the stripper goes to the H_2S absorption plant. A pressure relief valve on the stripper vents to the flare.

The stripped water then flows to an aeration column where it is contacted counter-currently with an air stream and caustic and is oxidized to non-odorous thiosulfate. The resulting foul air from this vessel is sent to the firebox of the vacuum unit heater for deodorizing.

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Figure 7.6.6. ACTIVITY STATUS REPORT FROM AN INSPECTION MADE OF A SOUR WATER OXIDIZING UNIT AT AN OIL REFINERY

The water flows from the bottom of the aerator through a cooler to the covered waste-water separator.

Prior to the introduction of the air pollution control program, the principle sources of air pollution at this unit resulted from the introduction of (1) mercaptans from the neutralizing tank to the burners of the vacuum unit heater, and (2) the H_2S from the waste-water stripper column to the refinery fuel gas system. The APCD test team determined that previously 0.5 ton/day of H_2S was contributed by this unit to the refinery fuel gas system. This is equivalent to a loss of 2000 lbs day of SO_2 to the atmosphere. After studying data disclosed by extensive physical inspection, testing, and industrial cooperation on waste gas streams throughout the refinery, Rule 62 was introduced to control those waste gas streams to be incinerated and containing significant quantities of sulfur derivatives. To comply with this rule, this refinery adopted the following solutions to meet the problems resulting from its particular operating methods:

a. Enlarged its H_2S absorption facility.

b. Made provision for introduction of condensable mercaptans into the cracking plant for conversion of H_2S and its eventual recovery.

The waste gas stream now burned in the vacuum unit heater was found to comply with Rule 62 during a test conducted by the APCD test team on 10-13-58.

Negligible mercaptan odors were noted in the vicinity of equipment at this time. Equipment was in good condition and operating under permit conditions and requirements. No visible emissions were observed at this time from the vacuum heater. A sample of treated water taken from the cooler (after oxidation) was free of obnoxious odors.

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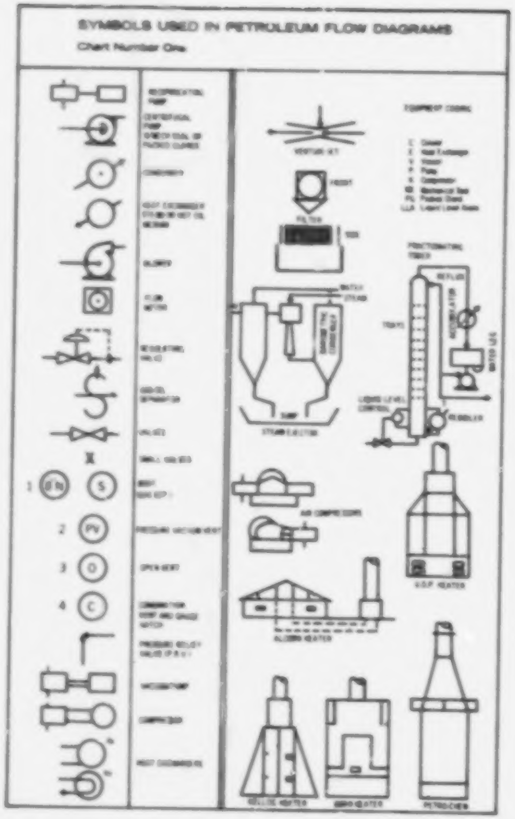
Figure 7.6.6. ACTIVITY STATUS REPORT FROM AN INSPECTION MADE OF A SOUR WATER OXIDIZING UNIT AT AN OIL REFINERY (Continued)


SYMBOLS USED IN PETROLEUM FLOW DIAGRAMS
Chart Number One
EQUIPMENT CODING
FILTER
STEAM EJECTOR
FRACTIONATING TOWER
REFLUX
LIQUID LEVEL CONTROL
REBOILER
AIR COMPRESSOR
PETROCHEM
1
2
3
4
S
PV
O
C

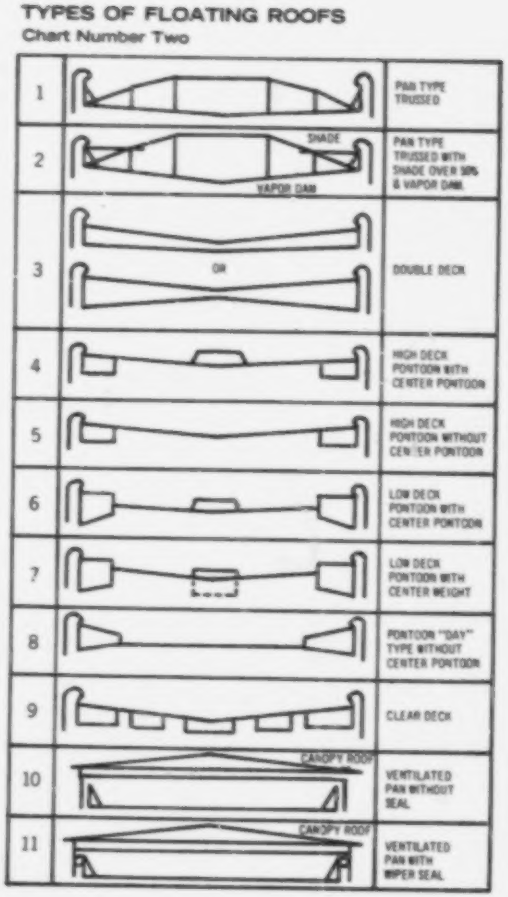

TYPES OF FLOATING ROOFS
Chart Number Two
1
PAN TYPE TRUSSED
2
SHADE
VAPOR DAM
PAN TYPE TRUSSED WITH SHADE OVER 50% & VAPOR DAM
3
OR
DOUBLE DECK
4
HIGH DECK PONTOON WITH CENTER PONTOON
5
HIGH DECK PONTOON WITHOUT CENTER PONTOON
6
LOW DECK PONTOON WITH CENTER PONTOON
7
LOW DECK PONTOON WITH CENTER WEIGHT
8
PONTOON "DAY" TYPE WITHOUT CENTER PONTOON
9
CLEAR DECK
10
CANOPY ROOF
VENTILATED PAN WITHOUT SEAL
11
CANOPY ROOF
VENTILATED PAN WITH WIPER SEAL

Figure 7.6.7. SYMBOLS USED IN PETROLEUM FLOW DIAGRAMS

BULK PLANT DATA

Figure 7.6.8. BULK PLANT DATA SHEET

TRUCK LOADING INSPECTION DATA SHEET

			GAL/DAY GASOLINE TO TRUCKS		SPOUTS						DATE	
COMPANY	LOCATION	RACK NO. OR NAME	AVERAGE	MAXIMUM	TOTAL	OVER 4# RVP	UNDER 4# RVP	RULE 61	PERMIT STATUS	RECHECK	CONTROLS FIRST USED	INSPECTED BY
Sunrise Oil Company	1325 Court St. Onyx, Calif.	1	23,000	28,500	5	2	3	2	A-7432		12-1-56	J.R.H.
"	"	2	26,000	30,000	6	2	4	2	A-4733		"	J.R.H.
"	"	1	24,500	47,000	5	2	3	2	A-4732	7-8-59		J.R.H.
"	"	2	26,000	30,000	7	2	5	2	P.R.	7-8-59		J.R.H.

Figure 7.6.9. TRUCK LOADING INSPECTION DATA SHEET

From this form, the total losses of hydrocarbons are determined using the following emission factors:

- Emission of hydrocarbons in gallons from uncontrolled equipment--Approximately 1/10 of 1 percent of the average gallon throughput per day.
- Emission of hydrocarbons in gallons from controlled equipment--8 percent of the above.

c. Oil-Effluent Water Separator Inspection

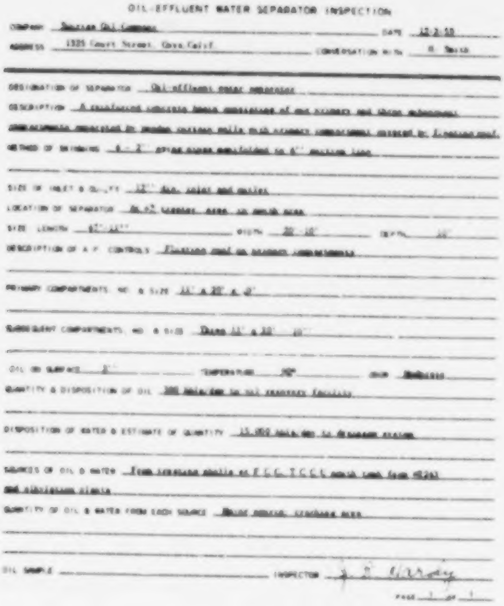
The example shown in Figure 7.6.10 is of a single refinery oil-effluent water separator which derives its influent from treating vessels, south tank farm, thermal and catalytic cracking units, and alkylation plants in the general cracking area of the refinery. The influent waste water is traced on the flow diagram by the inspector. The description of the controls, (i.e., "floating roof on primary compartments") and other information indicates whether the equipment is in compliance with pertinent rules.

d. Tank Inspection Report (Figure 7.6.11)

This inventory form records the type of tank, vapor control, function, dimensions, products stored, Reid vapor pressure, storage temperature, etc., of each tank to determine compliance with rules.

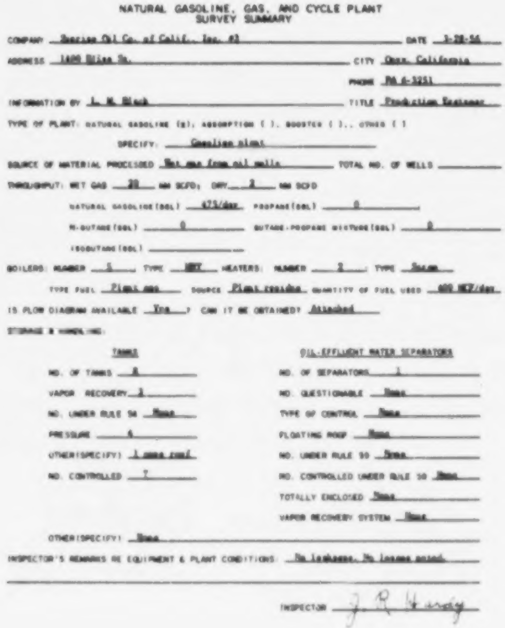
e. Data Sheet for Natural Gasoline, Gas, and Cycle Plants

This form, illustrated in Figure 7.6.11, provides for inventory of plants such as those named, which may be located apart from refinery facilities, but in proximity to crude oil production facilities. Information to be recorded includes the status of tanks and separators subject to emission control regulations.



OIL-EFFLUENT WATER SEPARATOR INSPECTION

Figure 7.6.10. OIL-WATER SEPARATOR INSPECTION SHEET



NATURAL GASOLINE, GAS, AND CYCLE PLANT
SURVEY SUMMARY

COMPANY Sunrise Oil Co. of Calif., Inc. #1 DATE 3-28-56

ADDRESS 1400 Bliss St. CITY [illegible], California

PHONE PA 6-3251

INFORMATION BY L. M. Black TITLE Production Engineer

TYPE OF PLANT: NATURAL GASOLINE (x), ABSORPTION ( ), BOOSTER ( ), OTHER ( )

SPECIFY: Gasoline plant

SOURCE OF MATERIAL PROCESSED Wet gas from oil wells TOTAL NO. OF WELLS

THROUGHPUT: WET GAS 20 MM SCFD; DRY 3 MM SCFD

NATURAL GASOLINE (BBL) 475/day PROPANE (BBL) 0

N-BUTANE (BBL) 0 BUTANE-PROPANE MIXTURE (BBL) 0

ISOBUTANE (BBL)

BOILERS: NUMBER 5 TYPE HRT HEATERS: NUMBER 2 TYPE Steam

TYPE FUEL Plant gas SOURCE Plant residue QUANTITY OF FUEL USED 400 MCF/day

IS FLOW DIAGRAM AVAILABLE Yes ? CAN IT BE OBTAINED? Attached

STORAGE & HANDLING:

TANKS	OIL-EFFLUENT WATER SEPARATORS
NO. OF TANKS 8	NO. OF SEPARATORS 1
VAPOR RECOVERY 3	NO. QUESTIONABLE None
NO. UNDER RULE 56 None	TYPE OF CONTROL None
PRESSURE 4	FLOATING ROOF None
OTHER (SPECIFY) 1 open roof	NO. UNDER RULE 59 None
NO. CONTROLLED 7	NO. CONTROLLED UNDER RULE 59 None
	TOTALLY ENCLOSED None
	VAPOR RECOVERY SYSTEM None

OTHER (SPECIFY) None

INSPECTOR'S REMARKS RE EQUIPMENT & PLANT CONDITIONS: No leakage. No losses noted.

INSPECTOR J. R. Hardy

Figure 7.6.11. NATURAL GASOLINE, GAS, AND CYCLE PLANT SURVEY SUMMARY

2. Inspection Points and Reinspection Procedures

In order to maintain current information on the full extent and status of refinery air pollution problems and potential problems, it is desirable to conduct major resurveys on a periodic basis. Occasionally major surveys may appropriately be conducted in cooperation with other agencies, for joint objectives. However, for routine surveillance, scheduled inspections of individual refinery units serve adequately. Frequency of the inspections scheduled for any given unit will be consistent with the expected potential of that type of unit for the development of problems.

Most inspections of process units in refineries are arranged in advance, as a part of the systematic programming of inspections. Such arrangements are necessary in order to assure that the process unit is in operation, that the appointed specialist in the plant is available, and for safety precautions and guidance. When the process unit is ready for reinspection, the inspector checks out the field file and reviews the previous reports, and then proceeds to the inspection.

3. Environmental Observations

The environment in the vicinity of refineries and other petroleum operations should be periodically surveyed for odors and for damage to vegetation and materials. Findings should be compared with observations of residents in neighboring communities. Soiling of surfaces of automobiles, residences and other structures should be noted and, where found to be severe, should be investigated. In particular, any pattern of increasing intensity of soiling or staining in the immediate vicinity of the subject facility should be studied, to aid in the possible detection of previously unrecognized emissions.

Odors of hydrocarbon vapors and gases are likely to be particularly prevalent near petroleum production and refining facilities. When intense, they indicate the occurrence of high emission levels, since odor thresholds for these compounds are relatively high and their quality not especially offensive.

Sulfur compounds associated with crude oil production and with some refinery operations are more readily detectable by odor. Sulfur dioxide may be produced by combustion of fuels or waste gases, for example in boilers, catalyst regenerators, incinerators and flares. This gas has an acrid, suffocating odor with a threshold of about 1 ppm. Reduced sulfur compounds, including hydrogen sulfide, various mercaptans and other sulfur-bearing organics, have characteristically highly offensive odors and very low threshold levels, which have been estimated at less than 1 ppb. (See, for example, Douglass.(9))

In reporting on occurrences of odors allegedly caused by petroleum facilities, the inspector should note wind conditions (speed as well as direction) at the time of his observations, and he should develop a systematic procedure for patrolling and for characterizing odors.

Odors may be described on an intensity scale in terms of subjective evaluation, or standardized procedure may be established, using a scentometer or other comparison device. A community odor pannel can help to establish the significance of day-to-day variations in odor intensity and quality of the ambient atmosphere, as well as to alert the inspector to the occurrence of unusual conditions.

Sulfur compounds, particularly hydrogen sulfide, can discolor and damage lead-based paints sometimes found in residential areas. They also accelerate tarnishing of silver and copper surfaces.

Sulfur dioxide and trioxide may also be responsible for certain types of damage to vegetation, causing yellow to brown blotchy spots on many varieties, and occasionally a sort of pock-marking injury which may be associated with sulfuric acid mist formed from the trioxide. Diagnosis of plant damage due to air pollutants is difficult, however, and should be confirmed by a consultant experienced in the field.(10)

4. The Physical Inspection

The objectives of the air pollution inspector are not only to determine which elements of the operation are affected by the Rules and Regulations but to determine as well the degree of compliance to them. His inspection procedures are adapted to the specific air pollution requirements governing the type of unit being inspected.

Safety is a prime consideration and all refineries have standard safety procedures for employees and visitors. Accordingly, the inspector is equipped with a hard hat, goggles, safety flash light; H_2S indicator; any other safety device the specific type of unit being inspected calls for.

The inspector is accompanied to the unit or units to be inspected, by the air pollution representative within the plant or by such other informed refinery personnel as he might indicate.

General unit or plant compliance is determined through sensory evidence, examination of current and past records, plans, recorder charts and gauges, obtaining samples for laboratory analysis, on-the-spot testing or calling for a mobile field test unit for more extensive determination of suspected sources of noncompliance.

a. Investigation of the Methods Used and the General Efficiency Achieved in Controlling the Release of Pollutants to the Atmosphere from Process (Basic Equipment) Units

The inspector determines plant procedures employed during start-ups, shut-downs and equipment malfunctions, to control or eliminate the discharge to atmosphere of noxious or malodorous emissions through the purging or depressuring of tanks or vessels. These include the installation of special instrumentation, e.g., high level or high pressure alarms, liquid knock-out drums on fuel gas systems, pressure relief or manually controlled discharge from process equipment to blow-down vessels of either variable or fixed capacity which are served by vapor recovery compressors, flare systems or both, and, where emissions are a factor, fixed roof tankage tie-in to properly sized vapor recovery or fume disposal systems. Loading racks should be tied to vapor control systems when the product being loaded has a significant vapor pressure.

b. Determination of Quality of Maintenance on Such Points as Manual, Pressure Vacuum Valves, Flanges, Pump Glands, Gauge Hatches, etc., which May be a Source of Leakage

Such emissions are primarily recognized by sensory evidence and their detection depends on the ability of the inspector to recognize the odor and to trace it to its point of origin.

The inspector must also note any visible air turbulence caused by light hydrocarbon leakage, frosting of valves or pump glands caused by light hydrocarbon evaporation, liquid leakage, local area discolorations caused by vapor condensate, visible emissions or changes in flow (surging) of an emission, extinguished flare pilot lights or detection of audible gas leaks. These may disclose a violation or a potentially critical situation that could be corrected in time.

c. Procedures Used in Controlling Air Contaminants and Odors Resulting from Disposal of Process Waste Effluents

The refinery inspector should thoroughly survey the sour water, waste water, sour gas, spent caustic and acid sludge gathering and processing and fume disposal systems.

Even though in a modern refinery most of these streams are "treated," their extremely noxious and malodorous characteristics make even the most isolated uncontrolled streams a potential source of air pollution problems.

Wherever possible, the inspector should point out conditions having a high air pollution potential so that the refinery technical staff may have the opportunity to assess the problem and arrive at a solution. More effective use of existing control equipment is achieved by extending its service to as many uncontrolled sources as is possible without overloading its capacity.

The inspector may find (1) isolated streams of sour gas fuel untreated for H_2S removal and recovery; (2) sour water discharged to open drains with live steam which has not been first deodorized by processing in sour water oxidation or H_2S stripping facilities; (3) odors and hydrocarbons emitted to the atmosphere from oil-water separators; (4) malodorous or noxious acid sludge, stored in uncontrolled tanks which release fumes and odors due to breathing and filling losses, or loaded into tank cars and trucks with similar results.

e. Investigation of Efficiency, Operating Load and Maintenance of Control Equipment

The effective operation of various control systems in a refinery is of basic importance to efficient air pollution control. Such equipment as cyclones, electrostatic precipitators, vapor recovery plants are subject to severe corrosion and other destructive forces which reduce air pollution control efficiency. In addition, a change in process feed or feed rates due to altered product requirements may also result in overloaded or otherwise upset operating conditions in the air pollution control system.

In the case of a vapor recovery system serving tankage, peak loads develop in the morning hours when the heat of the sun produces maximum volumes of hydrocarbon vapors in the space above the liquid. Uneven loading schedules at tank truck loading facilities tend to create a similar situation.

Since a gradual reduction in control efficiency does not always alter the effective operation of the process unit, it may not be noted by operating personnel until a major breakdown occurs accompanied by a serious air pollution situation such as a public nuisance. It is therefore essential for adequate air pollution control that such areas be inspected regularly and frequently.

This type of inspection is sometimes more complex. Sensory evidence such as visible discharge and odors may be disclosed by thorough physical inspection and may be sufficient in some situations to determine noncompliance or abnormal operation (breakdown), i.e., Ringelmann number readings, excess hydrocarbon vapor discharge from vapor controlled tankage, etc. However, in other cases, sensory evidence may only be a preliminary or corroborating step to the investigation, either because the regulations affected call for evidence not obtainable in this manner, (e.g., percentage sulfur in the fuel oil, H_2S grain loading in gaseous products burned and its btu value, weight of particulate discharge, concentration of SO_2 in discharge of flue gas) or because the control equipment does not discharge a waste effluent directly to the atmosphere. In such cases the inspector must either rely on data indicating temperature, density, pressure, vacuum or throughput recorded on gauges, continuous recorders, high level or density alarms, voltmeters and ammeters, or he must provide for special testing.

Another aid to the inspector is the information incorporated in applications to operate the equipment. The permit status of equipment should be routinely checked, in order to detect any changes in equipment or process that might invalidate an existing permit, or conflict with variance conditions.

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VII. CHEMICAL PLANTS

A. NATURE OF SOURCE PROBLEM - UNIT PROCESSES AND UNIT OPERATIONS

The definition of what constitutes a chemical industry rests more on accepted practice than on clearly distinguishing features. The processing of metal ores, the manufacture of synthetic rubber and pharmaceuticals, and the production of synthetic fertilizers all involve significant chemical reaction steps. However, in each case the industries are so large and the end use of the products so clearly visualized that they have come to be separately classified.

Nevertheless, the chemical industry can be broadly classified as one in which a basic, intermediate, or end use chemical compound is produced through one or more chemical reactions, followed by a series of separation and purification steps. A few examples of some of the chemical products are chlorine, sulfuric acid, nitric acid, phosphoric acid, caustic soda, ammonia, soda ash, and synthetic organic chemicals including elastomers, fibers, resins, plastics, pesticides, dyes, adhesives and solvents.

Both gas phase and particulate air contaminants may result from chemical plant processes. Gaseous contaminants may be either true gases or vapors arising from volatile liquids and solids. Contaminants may be unreacted starting materials, unwanted by-products, or non-recovered product.

In many cases contaminants arise from the purging of inert gases that are deliberately or inadvertantly introduced by a process. For example, if air is used as a source of oxygen for an oxidation step in a chemical process, the nitrogen remaining must be vented to the atmosphere. Unless adequate controls are utilized some air contaminants may be released along with the vented gases.

In many cases, gaseous products of a reaction are absorbed in water (for example, mineral acids). A small amount of gaseous material may not be absorbed and thus lost to the atmosphere unless otherwise controlled in what are known as tail gases.

Volatile organic liquids are a problem mainly during their storage and transfer. Vapors of these materials may be lost as a result of filling and breathing losses (see Section VI, Petroleum Refineries).

Liquid and solid particulates may be formed from gaseous reactions, gas-liquid reactions, gas-solid reactions, drying operations (powders), calcining, attrition losses, materials handling, and from fluidized catalyst beds, to give only a partial list of sources.

B. PROCESS DESCRIPTION - UNIT PROCESSES AND UNIT OPERATIONS

Chemical engineers involved in the design of chemical plants have for many years classified commonly used reactions and manufacturing steps into two broad groups known as (1) unit processes, and (2) unit operations. Unit processes are those procedures which involve a chemical change in one or more reactants. Unit operations generally involve only physical changes.

The utility of the above concepts lies in the ability to use unified design theories for most of the manufacturing steps required for even a very complex manufacturing process. For the purposes of this section the use of these classifications is intended to allow a broad look at the industry without undue detail. Relatively complete individual treatment is provided in Parts D and H of this section in the case of two large chemical industries--sulfuric acid manufacturing and vinyl chloride production.

1. Unit Processes

The fundamental reactions that may be involved in a chemical manufacturing industry would include decomposition, double decomposition, addition, substitution, isomerization, coupling, oxidation, reduction, and polymerization. Specific examples of these general reactions, which are in rather widespread use, are shown in Table 7.7.1. Groggins(1) presents a detailed review of most of these processes. A brief discussion of the air pollution emission potential of several of these processes follows.

a. Nitration

Nitration involves the formation of organic nitro compounds and is usually accomplished by a mixture of nitric and sulfuric acids. One of the principal potential sources of air pollution would be the recovery by concentration of spent nitric acid. Nitrogen oxides may be released unless specific control measures are utilized. Figure 7.7.1 is a schematic flow diagram of a methane nitration process for the production of nitromethane. In this process the product nitromethane and unreacted nitric acid are condensed following the reaction and the nitromethane recovered by distillation. The dilute (spent) nitric acid is fed to an absorption tower through which non-condensible reaction gases containing nitrogen oxides are passed. Following the absorber some of the inert gases, mostly nitrogen, must be purged. Small quantities of nitrogen oxides may also be lost.

b. Sulfonation and Sulfation

These processes use oleum and sulfuric acid to produce a great variety of organic sulfonates and sulfates. Sulfur oxides may be lost in small quantities.

Table 7.7.1 COMMONLY USED UNIT PROCESSES

Unit Process	Product Examples
Nitration	Nitromethane
Amination by Ammonolysis	Aniline
Diazotization and Coupling	Benzenediazonium chloride
Halogenation	Vinyl chloride
Sulfonation and Sulfation	Naphthalene sulfonic acid
Hydrolysis	Glycerol
Oxidation	Quinone
Hydrogenation	Methanol
Friedel-Crafts Reactions	Ethyl benzene
Polymerization	Polyethylene
Calcining	Silica gel

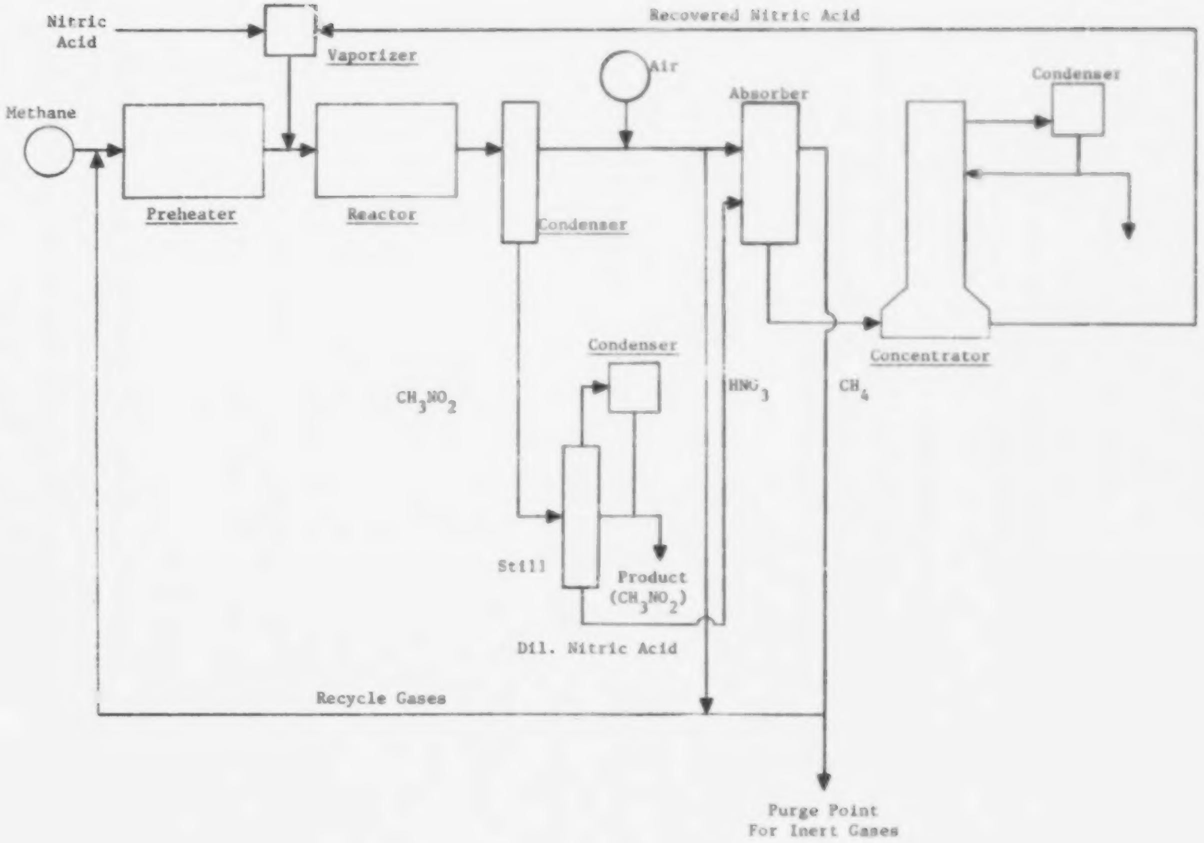

Nitric Acid
Vaporizer
Recovered Nitric Acid
Methane
Preheater
Reactor
Condenser
Air
Absorber
Condenser
Concentrator
Condenser
CH3NO2
Still
Product (CH3NO2)
Dil. Nitric Acid
HNO3
CH4
Recycle Gases
Purge Point For Inert Gases

Figure 7.7.1 FLOW DIAGRAM FOR NITRATION OF METHANE

c. Halogenation

Halogens, i.e., chlorine, bromine and iodine are added to organic compounds by this process. Either the halogen or the hydrohalogen may be lost to the atmosphere. (See the vinyl chloride process described later in this section.)

d. Amination by Ammonolysis

Amination by Ammonolysis describes the process of amine production using ammonia. Tail gases may contain ammonia after the condenser serving the purification rectifier.

e. Hydrolysis

In this process a portion of the water molecule is made to replace another substituent. For example, phenol is produced by the hydrolysis of chlorobenzene. Acid vapors (hydrogen chloride in the case of phenol production) may be lost without proper control.

f. Oxidation

Describes the process by which the oxidation state of a substance is increased. For example, air may be used to oxidize acetaldehyde to acetic acid. The nitrogen remaining after this process must be vented (purged) and may contain traces of reactants or products. A great number of oxidizing agents, including chlorine sodium chlorite, permanganates, chlorates, chromic acid, nitric acid, and nitrogen tetroxide may be used under this general heading.

g. Hydrogenation

Hydrogenation involves the addition of hydrogen. Examples would include hydrogenation of vegetable oils and the production of methanol from carbon monoxide and hydrogen. Again the purging of inert gases may contain reaction by-products. In the future this process may be used on a large scale for coal gasification.

h. Friedel-Crafts Reactions

Friedel-Crafts includes a large group of reactions in which aluminum chloride is used as a catalyst. Hydrogen chloride may be released as a by-product.

2. Unit Operations

That sub-group of unit operations which has in common the transfer of material from one homogeneous phase to another is described by the term mass transfer.(2) Except for the transfer and size classification of dry materials in particle form, the mass transfer operations are, from the point of view of air pollution control, the most important of the unit operations.

That group of operations grouped under the mass transfer term is differentiated from purely mechanical separation techniques by the fact that they utilize differences in vapor pressure and solubility rather than variations in particle size and density as the basis for separation. Several of the more important mass transfer operations together with examples of possible atmospheric emissions are given in Table 7.7.2.

3. Control Methods

Air pollution control methods used in chemical process plants do not differ inherently from those used in other industries. Those differences which do exist are largely a matter of degree. In general there are probably more air pollution problems in chemical plants related to fixed gases, volatile vapors, and liquid mists than there are those related to solid aerosols and combustion contaminants.

Table 7.7.2 EXAMPLES OF MASS TRANSFER OPERATIONS AND AIR POLLUTANT POTENTIAL

Mass Transfer Operation	Principle	Air Pollutant Example
Absorption	Soluble gas removed from an inert gas by absorption in a liquid.	Residual ammonia lost along with vented air after absorption by water.
Evaporation and Drying	Volatile liquid removed from non-volatile liquid or solid by application of heat.	Removal of solvent from desired by-product by passage of heated air or spray drying of powders and flake material.
Distillation	Separates by volatilization a mixture of miscible and volatile substances. Vapor must differ in composition from boiling liquid.	Loss of alcohol vapors after separation of alcohol and water by distillation.
Condensation	Removal of condensible vapor from inert gas by cooling.	Loss of odorous materials to water used in contact (barometric) condenser, and subsequent loss from water.

The techniques most commonly used for air pollution control are listed below and described more completely in Chapter 2.

Control Methods Common to the Chemical Industry

Absorption
Adsorption
Condensation
Vapor Recovery
Fume Incineration

C. INSPECTION POINTS - UNIT PROCESSES AND UNIT OPERATIONS

Perhaps the single most important factor in the inspection of a chemical plant is the degree to which the inspector is familiar with the process(es) involved. One of the best means of preparation is to examine a detailed process flow diagram and accompanying descriptive text, identifying all possible sources of pollution and the location of all vents to the atmosphere. At the time of inspection this flow sheet can be much more easily related to the plant layout plan and the equipment itself. It is nearly inevitable to the uninitiated that continuous flow chemical plants (as well as petroleum refineries) will resemble a jungle of vessels, pumps, and piping.

Once on the plant site, all vents, regular and emergency, should be located on the plot plan indicating approximate size and height. Where relatively small quantities of inert gases (such as air) are involved the vents may actually be quite small and easily overlooked.

The inspector should obtain an up-to-date description of all processes, including feed rates and composition and the variations that occur in these items. Should pollutant emissions be unusually sensitive to production rates, this data on production should be obtained.

The inspector should become familiar with both internal and external conditions during normal operations, i.e., control instrumentation readout, presence of visible emissions, and detectability of odors in the surrounding area.

One useful approach is to make inquiry as to the nature and probability of occurrence of conditions which would necessitate the instigation of emergency venting procedures. Of similar importance is the determination of the effect of a rapid shut-down of all operations.

Non-routine operations, such as start-up, catalyst regeneration, scheduled maintenance, etc., should be studied as to their effect on air pollutant emissions.

Finally, regular surveillance of the surrounding area should be conducted to examine for evidence of possible effects related to emissions from the plant in question. Should complaints be received, it will be extremely important to make a timely determination of the plant operating conditions associated with the time of the detected effects. Meteorological data related to the transport and diffusion of contaminants, and detectability of effects should be obtained. These include wind speed and direction, atmospheric stability, and relative humidity. In most cases the inspector should make independent estimates of these parameters even though he suspects such data may be available from weather instrumentation.

D. NATURE OF SOURCE PROBLEM - SULFURIC ACID MANUFACTURING

The manufacture of sulfuric acid, regardless of the process, results, to some degree, in the emission of unconverted sulfur dioxide and unabsorbed sulfuric acid mist. In plants using the lead chamber process, nitrogen oxides may be discharged in concentrations nearly as high as the sulfur dioxide emitted. Of these nitrogen oxides, usually 50-60% is nitrogen dioxide.(3) Only traces of nitrogen oxides are normally emitted from the contact process sulfuric acid plants, which account for over 90% of the sulfuric acid produced in the United States.

Variable amounts of a variety of mineral dusts may be lost from plants using smelter or ore roasting gases as a source of sulfur. Sulfuric acid vapor as opposed to sulfuric acid mist, will be in equilibrium with the sulfuric acid produced and will be lost in small quantities.

Other small, but possibly nuisance forming losses from sulfuric acid plants could include wind blown raw sulfur from storage piles, odors from spent or sludge acid storage tanks, leaks of sulfur dioxide or acid mist from process vessels under pressure, sulfur trioxide vapor from oleum storage and transfer.

Unless considerable care is taken there is great potential for increased emission rates of sulfur dioxide during start-up operations.

Although sulfuric acid manufacturing accounts for only about 2% of the total sulfur oxides emitted to the atmosphere in the United States (approximately 600,000 tons of SO_2 per year out of a 28,600,000 tons per year total in 1966)(4) any given sulfuric acid plant can be a significant local source. As compared to fuel burning sources of sulfur oxides, sulfuric acid plants are distinguished by several features which can add to the local nuisance potential--(1) low tail gas temperatures and sometimes short stacks which in combination result in poor stack gas dispersion and occasionally high ground level concentrations of sulfur dioxide and acid mist, (2) presence of sulfuric acid mist as well as sulfur dioxide, and (3) odors from raw materials and the finished product.

E. PROCESS DESCRIPTION - SULFURIC ACID MANUFACTURING

The basic reaction in the manufacture of sulfuric acid is:

$$SO_2 + 1/2\ O_2 \rightleftharpoons SO_3$$

This reaction is exothermic with the higher equilibrium concentration of SO_3 being favored by lower temperatures. Slower reaction rates, however, accompany the lower temperatures necessitating a careful heat balance to achieve high SO_2 to SO_3 conversion at practical reaction rates. It is obvious from the equation above that SO_2 conversion is also favored by high O_2 to SO_2 ratios.

Two processes are in use in the United States for the manufacture of sulfuric acid. The older chamber process produces a relatively weak 60°Be (77.7%) acid and accounts for less than 10% of the production in the United States. Nitrogen oxides are used as a catalyst for the conversion of sulfur dioxide to sulfur trioxide. The contact process involves the direct conversion of sulfur dioxide to sulfur trioxide over a vanadium pentoxide catalyst and produces concentrated sulfuric acid (98-100%) and various strengths of oleum (concentrated sulfuric acid having additional absorbed sulfur trioxide). All new sulfuric acid plants are of this type.

In both chamber and contact processes hydration of the sulfur trioxide takes place during absorption operations producing the sulfuric acid. The tail gases issuing from the final absorption tower contains excess air and any unreacted sulfur dioxide sulfuric acid mist, sulfur trioxide, sulfuric acid vapor, nitrogen oxides and other contaminants that might be present.

1. Chamber Process

Presently operating chamber plants in the United States use sulfur as the raw material for the production of sulfur dioxide used in the acid manufacturing process.(3) In the chamber process, as shown in

Figure 7.7.2, sulfur is burned to sulfur dioxide which is introduced together with nitrogen oxides (approximately equal proportions of nitric oxide and nitrogen dioxide) to the Glover tower. Here a series of complex intermediate reactions are initiated between the nitrogen oxides and the sulfur dioxide which culminate in the oxidation of sulfur dioxide to sulfur trioxide and the release of the nitrogen oxides. The nitrogen oxides which are recovered in the Gay-Lussac towers by absorption in chamber acid are also fed to the Glover tower for recycling in the process. Approximately 50% of the sulfuric acid is formed in the Glover tower with the remaining conversion taking place in large lead-lined chambers (thus the "Chamber" process).

The range of emissions of air contaminants from chamber sulfuric acid plants is approximately as shown below:(5)

SO_2	1500-4000 ppm
Acid Mist	5-50 mg/ft^3
NO_2	~1000 ppm
NO	~500 ppm

Emission levels are affected by the concentration of sulfur dioxide in the burner gas entering the Glover tower, the amount of nitrogen oxides in circulation, the ratio of nitrogen dioxide to nitric oxide, the throughput rate, and the temperature and concentration of acid entering the final Gay-Lussac tower. All other factors being equal, lower atmospheric temperatures generally result in somewhat reduced sulfur dioxide emissions because of the additional cooling of the lead chambers by ambient air.

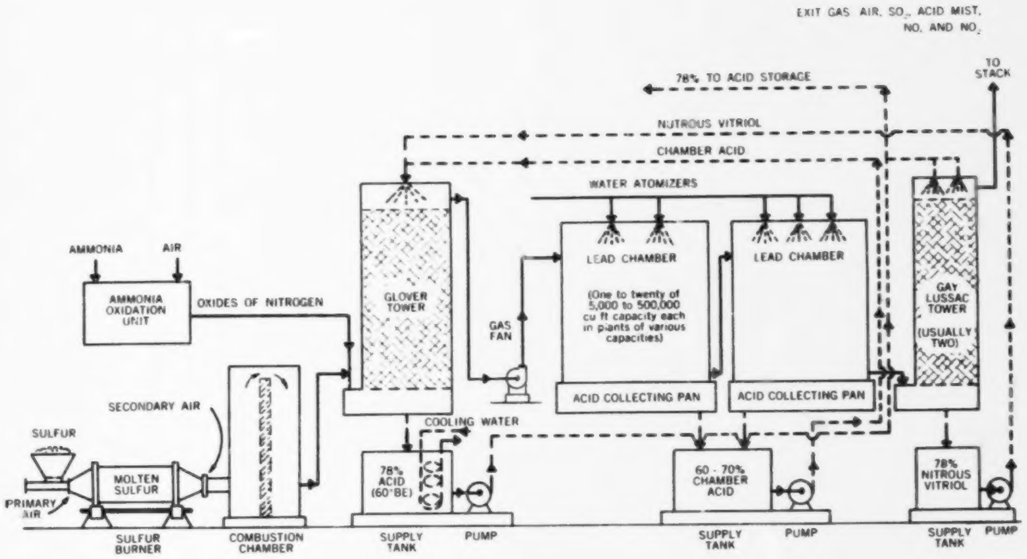

EXIT GAS AIR, SO$_2$, ACID MIST, NO, AND NO$_2$
TO STACK
78% TO ACID STORAGE
NUTROUS VITRIOL
CHAMBER ACID
WATER ATOMIZERS
AMMONIA
AIR
AMMONIA OXIDATION UNIT
OXIDES OF NITROGEN
GLOVER TOWER
GAS FAN
LEAD CHAMBER
(One to twenty of 5,000 to 500,000 cu ft capacity each in plants of various capacities)
LEAD CHAMBER
GAY LUSSAC TOWER
(USUALLY TWO)
ACID COLLECTING PAN
ACID COLLECTING PAN
SECONDARY AIR
SULFUR
PRIMARY AIR
MOLTEN SULFUR
SULFUR BURNER
COMBUSTION CHAMBER
COOLING WATER
78% ACID (60°BE)
SUPPLY TANK
PUMP
60 - 70% CHAMBER ACID
SUPPLY TANK
PUMP
78% NITROUS VITRIOL
SUPPLY TANK
PUMP

Figure 7.7.2. SIMPLIFIED FLOW DIAGRAM OF TYPICAL LEAD-CHAMBER PROCESS FOR SULFURIC ACID MANUFACTURE (BASED ON USE OF ELEMENTAL SULFUR AS THE RAW MATERIAL). (SOURCE: P.H.S., DIVISION OF AIR POLLUTION, Reference 3).

2. Contact Process

A variety of contact processes are used in the manufacture of sulfuric acid, differing principally in the source of sulfur and in the number of conversion stages used in the catalytic reactor. Differences in heat exchange equipment may occur, depending upon sources and demands for heat in the plant complex, but these differences should have relatively little impact on the air pollution potential of the plant. One likely future difference in new plants is the use of the double absorption process (see Chapter 2).

Contact plants burning elemental sulfur are sometimes known as "hot gas" plants and utilize a drying tower for the combustion air so as to minimize the amount of moisture entering the converter along with the sulfur dioxide and excess air. The presence of moisture in the converter results in the formation of sulfuric acid mist which must be removed from the tail gas. Plants using hydrogen sulfide from refinery operations, acid sludge, copper converter gases, and roaster gases from other sulfide ore smelters are often described as "wet gas" plants. In these plants reactor gases are dried and cleaned just prior to entering the converter. Combustion air for plants burning acid sludge and hydrogen sulfide is not dried as additional water is formed in the burner.

Figure 7.7.3 shows a schematic flow diagram for a modern 4-stage sulfur burning contact acid plant. In this plant atmospheric air is discharged from a pressure type blower into a drying tower through which 93-99% sulfuric acid is circulated as a drying agent. The dry air together with molten sulfur is charged to the sulfur burner in such a ratio as to produce a feed gas containing 7.5-8.5 mol% sulfur dioxide, about 13% oxygen, and a nitrogen balance. Should any hydrocarbon be present it will be burned to carbon dioxide and water.

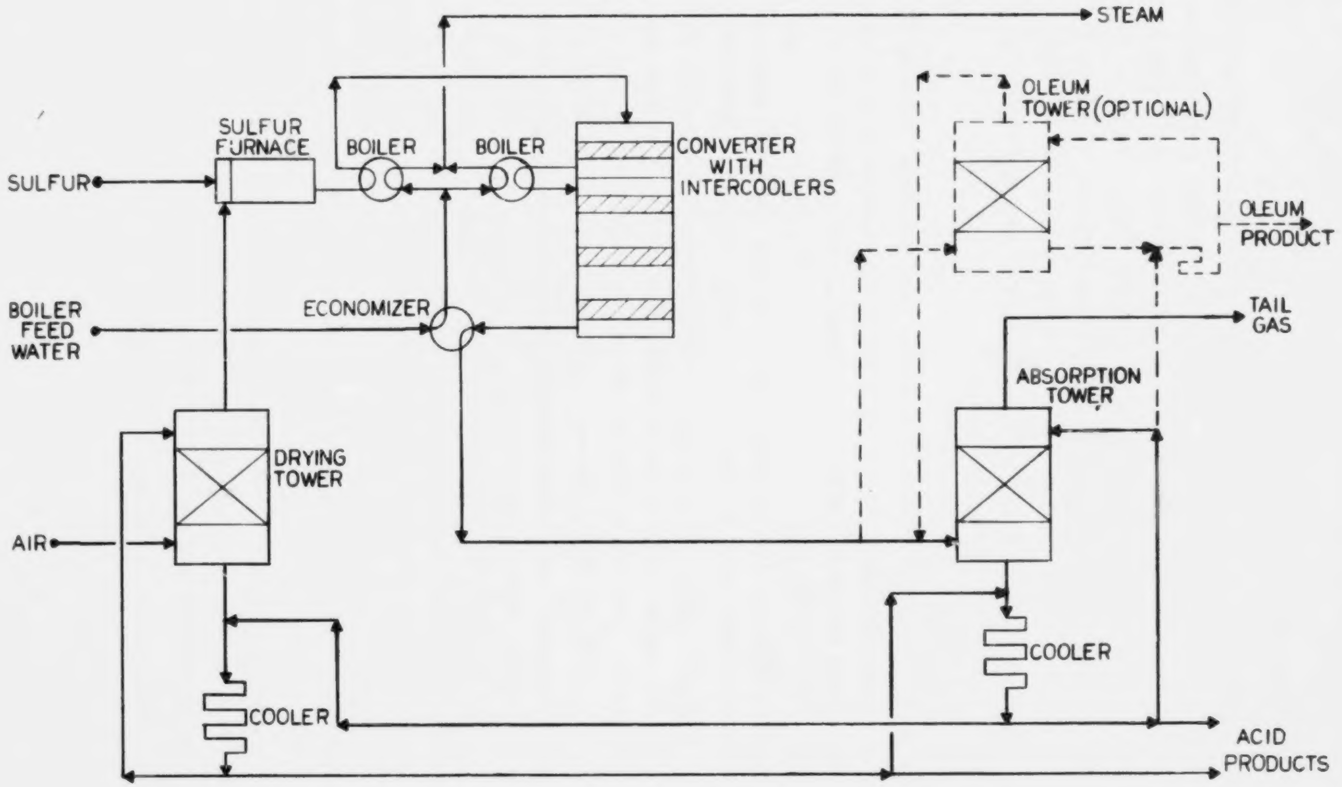

STEAM
SULFUR
SULFUR FURNACE
BOILER
BOILER
CONVERTER WITH INTERCOOLERS
OLEUM TOWER (OPTIONAL)
OLEUM PRODUCT
BOILER FEED WATER
ECONOMIZER
TAIL GAS
ABSORPTION TOWER
DRYING TOWER
AIR
COOLER
COOLER
ACID PRODUCTS

Figure 7.7.3. SCHEMATIC FLOW DIAGRAM OF SULFUR BURNING PLANT WITH FOUR-STAGE CONVERSION. (SOURCE: CHEMICO, Reference 5.)

The feed gases are cooled in a waste heat boiler to a temperature of 820°-840°F and then fed to the converter. Interstage cooling is necessary to remove the heat of reaction and to allow a satisfactory degree of reaction to take place. Conversion of sulfur dioxide to sulfur trioxide in this type of plant can range up to 96-98%.

The converter gas is cooled in an economizer used for heating boiler feedwater or in some other type of heat exchanger. The converted gases leave the economizer at about 450°F and enter the absorption tower where the sulfur trioxide is absorbed in a circulating stream of 98-99% sulfuric acid. In the event that oleum is to be produced, the converter gases first pass through the oleum tower where acid from the 98% absorber is circulated. The gases must be cooled to a lower temperature before entering the oleum tower than if only 98% acid were to be produced.

Unless additional control equipment is used, the tail gases leaving the absorption tower are discharged to the atmosphere at this point. Typical tail gas concentrations from a 4-stage sulfur burning contact acid plant are shown below:(5)

SO_2	1500-4000 ppm
Acid Mist	2-20 mg./SCF
SO_3	0.1-1.3 ppm

The "wet gas" type of contact plant using waste gases from metallurgical operations, or acid sludge and hydrogen sulfide from refinery processing is considerably more elaborate than the sulfur burning contact plant. Sulfur dioxide containing gas from smelters may be contaminated by metal fumes, dusts, acid mists, other gaseous impurities and water vapor. These must be removed by various dust collectors, mist precipitators and drying towers before the feed gases enter the converter. Plants based upon the use of acid sludge, spent acid or hydrogen sulfide are usually somewhat simpler than those using waste smelter gases in that there is less of a dust and fume contamination problem. Figure 7.7.4 shows a simplified flow diagram of a "wet gas" contact plant. Although the heat balance may be substantially different for this type of plant as compared to a sulfur burning plant, the process is essentially the same from the converter forward.

Some additional problems are encountered in plants utilizing waste gases from metallurgical operations due to the possible variations in sulfur dioxide content.

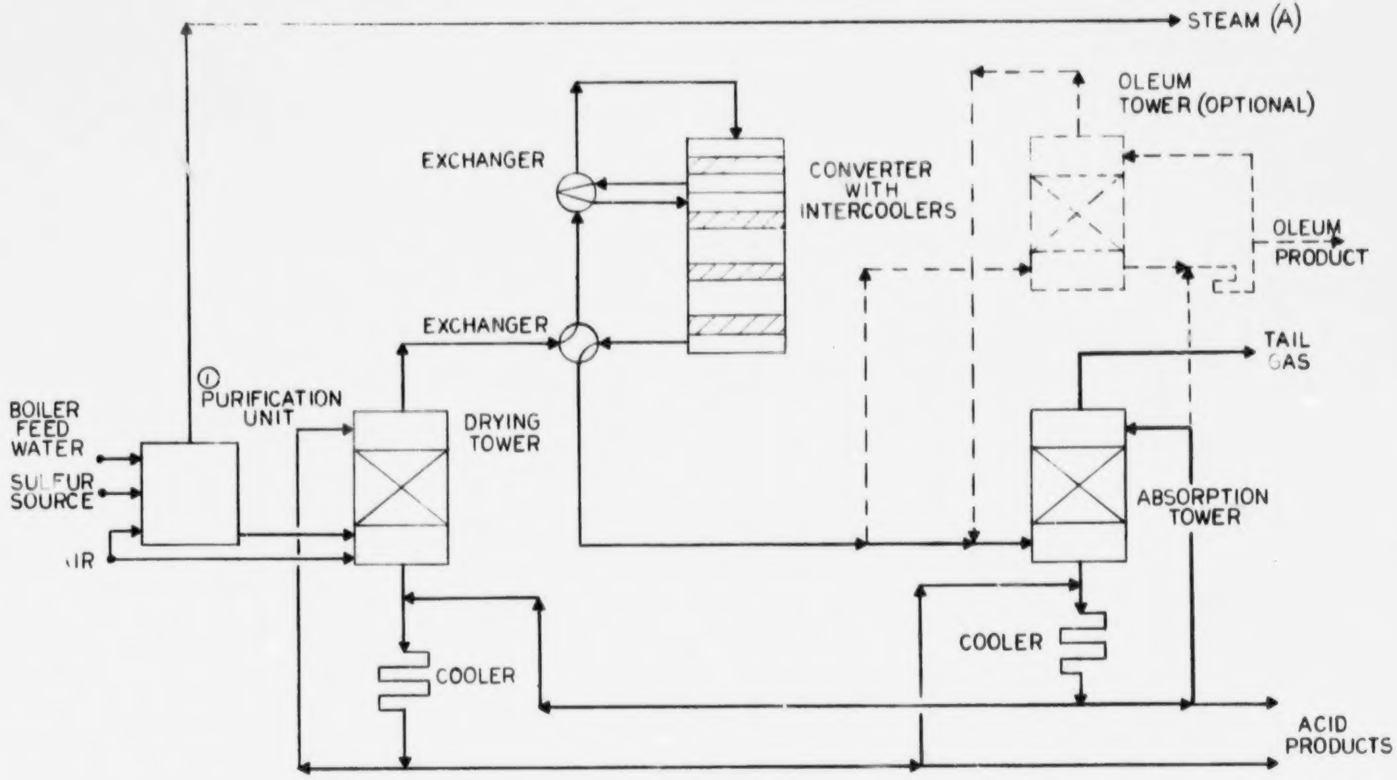
F. CONTROL METHODS - SULFURIC ACID MANUFACTURING

Emissions from sulfuric acid plants are in the main unconverted sulfur dioxide (gaseous) and sulfuric acid mist (liquid aerosol). Some nitrogen oxides may be lost from chamber plants and a small amount of unabsorbed sulfur trioxide may reach the final discharge stack. Any sulfur trioxide released will hydrate rapidly with atmospheric moisture and form additional sulfuric acid aerosol.

Control methods are usually considered separately for sulfur dioxide and acid mist but in one approach to SO_2 tail gas scrubbing a venturi scrubber is proposed which would also remove some acid mist.

1. Sulfur Dioxide Control

Most existing sulfuric acid plants can reduce SO_2 emissions to approximately 2000 ppm by operational control methods.(3) Reduction to levels of 500 ppm or lower would require process changes such as the installation of a dual absorption system, or would necessitate tail gas treatment.


STEAM (A)
OLEUM TOWER (OPTIONAL)
EXCHANGER
CONVERTER WITH INTERCOOLERS
OLEUM PRODUCT
EXCHANGER
TAIL GAS
① PURIFICATION UNIT
BOILER FEED WATER
SULFUR SOURCE
AIR
DRYING TOWER
ABSORPTION TOWER
COOLER
COOLER
ACID PRODUCTS

①INCLUDES COMBUSTION UNIT WHEN USING SLUDGE, PYRITE OR H_2S.

(A) STEAM IS GENERATED ONLY WHEN BURNING SLUDGE OR H_2S OR WHEN ROASTING PYRITE. NONE IS GENERATED WHEN USING A PURIFICATION UNIT ONLY, AS WITH SMELTER GAS.

Figure 7.7.4. SCHEMATIC FLOW DIAGRAM WET GAS PLANT WITH 4-STAGE CONVERSION. (SOURCE: CHEMICO, Reference 5.)

Operational methods of sulfur dioxide control basically involve enhancement of the sulfur dioxide conversion to sulfur trioxide. Any one or a number of the following methods might be used.

- Reduce the initial sulfur dioxide concentrations entering the converter.
- Reduce the ratio of SO_2 to O_2.
- Increase the number of converter stages.
- Increase the volume of catalyst.
- Change catalyst more frequently and improve distribution.
- Improve uniformity of feed conditions.
- Reduce feed gas impurities.
- Provide additional interstage cooling in converter and improve temperature control throughout the plant.
- Reduce throughput rate.
- Exercise additional care during plant start up.

Reductions in sulfur dioxide emissions from contact acid plants may also be achieved by incorporating the double absorption technique in the process. In this approach, which is mainly applicable to new plants, conversion of SO_2 to SO_3 is interrupted after two or three stages and the gas stream is fed to the first absorption tower. Effluent gas from this tower now having a very high O_2/SO_2 ratio is returned to the converter where the new equilibrium conditions favor an extremely efficient conversion of SO_2 to SO_3. Following an additional one or two stages of conversion the converter gas is introduced to the final absorption tower. Overall conversion of SO_2 to SO_3

of +99.5% is achievable with this process. Tail gas concentrations of 500 ppm SO_2 are readily attainable with the double absorption modification of the contact process. For existing plants, another absorption tower and probably some additional heat exchange equipment would be necessary.

To attain sulfur dioxide concentrations of very much less than 500 ppm, some sort of tail gas treatment would probably be necessary. In a recent report, prepared for the Air Pollution Control Office,(5) nearly 50 possible tail gas treatment schemes were listed with nine being selected for a more detailed review. Little use of tail gas treatment, however, is made in current practice. Two plants in the United States have used an ammonia scrubbing process on a full scale basis and one is engaged in pilot scale studies of the potassium sulfite-bisulfite (Wellman-Ford) process at the present time. This situation is likely to change over the next few years.(6)

2. Sulfuric Acid Mist Control

As can be seen from earlier portions of this section, acid mist emissions range from 2-20 mg/SCF (70-700 mg/M^3) for most of the sulfuric acid plants operating in the United States. Although sulfuric acid mist accounts for a relatively small proportion of the total sulfur losses (approximately 1-10%) from a sulfuric acid plant it is responsible for visible plumes and is associated with material damage and health effects at lower concentrations than is sulfur dioxide.

There are a variety of operational and process factors which affect acid mist emissions. Among these are:

- Improper concentration and temperature of the absorbing acid.
- Amount and concentration of oleum produced.

- High content of organic matter in the raw materials of a sulfur burning plant.
- High moisture content of the sulfur dioxide entering the converter.
- Stack cooling of sulfur trioxide gases leaving the converter, i.e., sudden cooling below the acid dew point, resulting in condensation of very small particles.
- Presence of nitrogen oxides, which can result from excessive temperatures in the sulfur combustion chamber, from nitrogen in raw materials, and from arcing in electrical precipitators.
- Insufficient acid circulation and lack of uniformity of acid distribution in the absorption tower.
- Improper type or dirty packing in the 98% absorber.

Many sulfuric acid plants utilize some form of collection equipment designed specifically for acid mist. The most common type is the two-stage knitted wire or Teflon^R mesh pad. Such pads operate at relatively low pressure drop (2-3" H_2O) and are effective for acid mist particles greater than 3 microns in size. For particles less than 3 microns in diameter, such as result from oleum producing plants, the efficiency is much lower (15-30%). These smaller particles are responsible for visible plumes and may be carried for considerable distances in the atmosphere.

Venturi scrubbers operating at a pressure drop of about 35-40" H_2O have been used on acid concentrators where most of the acid mist particles are $> 3\mu$ but recently have been proposed for combined use in removing both SO_2 and acid mist from sulfuric acid plants.(7) Such units would not be expected to be effective for mist removal from oleum plants.

The only devices capable of reducing all size ranges of acid mist to 0.1 mg/SCF are glass fiber filters and electrostatic precipitators. Glass fiber filters presently in use operate at about 8" H_2O pressure drop. Electrostatic precipitators operate at low pressure drops (about 1" H_2O) but are initially quite expensive. They are also rather large because of the low gas velocities necessary for efficient operation.

Table 7.7.3 summarizes the expected performance for the acid mist collectors.

G. INSPECTION POINTS - SULFURIC ACID MANUFACTURING

The inspection of sulfuric acid plants must take into account the interconnected, continuous nature of the manufacturing process, since there is essentially one point of emission for the major potential air contaminants. Though there may be some wind blown sulfur and even small amounts of sulfur dioxide and hydrogen sulfide from sulfur storage and melting, all the sulfur dioxide, sulfuric acid mist, and nitrogen oxides arising from the manufacturing process will be emitted from the final absorption tower or from the control equipment following the tower.

The emission potential of any given acid plant is dependent upon the type of process, age of the plant, whether or not oleum is produced, nature of the raw material, production rate, operating variables, and type of control equipment.

Table 7.7.3 EXPECTED PERFORMANCE OF ACID MIST COLLECTION SYSTEMS

System	Efficiency > 3 Microns	Efficiency < 3 Microns	Emission Level 99% Acid Plants	Emission Level Oleum Plants
Wire or Teflon Mesh	99+%	15-30%	to 2 mg/SCF	to 5 mg/SCF
Glass Fiber Filter	100%	95-99%	0.1 mg/SCF	0.1 mg/SCF
Electrostatic Precipitator	99%	100%	0.5 mg/SCF	0.1 mg/SCF
Venturi Scrubber	98%	Low	3 mg/SCF	Ineffective with < 3 micron mist

The major tasks the inspector performs include the following: determination of the nature of the process as it affects air contaminant emission; examination of operating conditions and relevant records; surveillance for plume appearance (if any); determination of contaminant emission rates, and investigation of possible property damage.

1. Environmental Surveillance

The only visual evidence of emissions from the contact process for sulfuric acid manufacture is the white plume associated in controlled acid mist having a particle size range generally less than three microns. Particles larger than this do not scatter light in the visual wave length range effectively and thus may be present but not visible. In the case of a chamber process plant it is possible that nitrogen oxides may be discharged from the Gay-Lussac tower in concentrations high enough so that the reddish-brown color of nitrogen dioxide can be seen.

Should there be a visible plume, the inspector may use it as a guide to locating those locations where ground level concentrations of sulfur dioxide and acid mist are high enough to be detectable by humans or to cause visible damage to materials and vegetation. Regardless of whether or not there is a visible plume the behavior of the plant effluent will be influenced by stack height, effluent gas temperature, wind speed and direction, atmospheric stability, and surrounding terrain. It may be desirable in some cases to utilize a diffusion model to estimate ground-level concentrations in the surrounding area by various averaging times and for differing atmospheric conditions. The application of these diffusion models is described in Turner's "Workbook on Atmospheric Dispersion Estimates."

Sulfur dioxide and sulfuric acid mist can cause localized damage to metals through corrosion and may attack a wide variety of building materials, causing discoloration and deterioration. These contaminants may also cause dyed fabrics of certain types to fade. Sulfur dioxide may cause acute or chronic leaf damage to plants. The symptoms most often observed are bleaching, yellowing, or chlorosis. Expert assistance is usually necessary to confirm the cause of material or vegetation damage, but the inspector may be trained to recognize prominent symptoms. The pattern of damage in the vicinity of a suspected source may provide valuable circumstantial evidence as to the probable cause of the damage.

2. Inspection of the Premises

a. Interview

In the case of a sulfuric acid plant most of the important information obtained in a plant inspection will be from the interview with the plant management. The continuous enclosed nature of the manufacturing process precludes obtaining extensive information by visual inspection alone.

The inspector will first wish to learn the specific details of the particular process employed in a given plant, such as the nature of the sulfur source and the range in composition and extent of contaminants present. Even in a sulfur burning plant the latter item can be important. The rated capacity and normal operating rate of the plant should be obtained. Information on start-up procedures and the frequency with which shut-downs and start-ups occur is desirable. Operating procedures and nature of control procedures and equipment should be secured. Some of the specific items of importance are SO_2 and O_2 concentrations entering the converter, temperatures at various points in the converter and absorption tower, and the concentration and temperature of the absorption tower acid. In some cases the inspector may be given the opportunity of examining operating records during the interview.

The inspector should obtain information on sulfur dioxide conversion efficiency, efficiency of any collection equipment used and data on the tail composition finally being discharged to the atmosphere. He should inquire about maintenance procedures and their frequency.

b. Physical Inspection

The inspector should first become familiar with the physical layout of the plant and prepare or obtain a plot plan showing the location of principal items of equipment.

He should inspect the sulfur storage area in the sulfur burning plant and determine the potential for wind blown sulfur dust losses. He should also investigate the possibility of hydrogen sulfide formation from molten sulfur containing hydrocarbon impurities.

Depending upon the type and age of the plant, some indicating and/or recording instrumentation may be employed. Some of the types which the inspector may have the opportunity of examining include:

- Temperature (process gas entering and leaving the several converter stages and absorption towers).
- Acid concentration (drying tower and absorption towers).

- SO_2 concentration (entering the converter, entering and leaving the absorption tower or tail gas scrubber).
- Miscellaneous flow and pressure measurements.

Tests for sulfur dioxide, oxygen, acid mist concentration, and nitrogen oxides often can be manually performed to supplement the above instrumentation.

The inspector should determine the capability of the plant to meet emission control regulations. These include limitations on the discharge of (1) sulfur dioxide in the effluent in excess of 4 lbs. per ton of acid produced (2 kgm per metric ton), maximum 2-hour average, (2) acid mist in the effluent in excess of 0.15 lb. per ton of acid produced (0.075 kgm per metric ton), maximum 2-hour average, expressed as H_2SO_4, and (3) a visible emission. In determining compliance the inspector should:

(1) Check the number of catalyst stages - older plants that have only two stages of catalyst typically have only 90-95% conversion of sulfur dioxide to sulfur trioxide. Plants with three stages of catalyst will typically have a 96-98% conversion of sulfur dioxide to sulfur trioxide. These conversion efficiencies are equivalent to emission rates of 26 to 52 lbs. per ton of acid produced.

(2) Determine types of acid mist eliminators. Mesh mist eliminators with double pads will collect efficiently acid spray and mist from a properly operated 98% acid absorber, but not acid mist from an oleum tower. Teflon mist eliminators or high energy scrubbers are often used to collect acid mist less than three microns in size to meet an emission limit of .15 lb. per ton of acid, maximum 2-hour average, expressed as H_2SO_4 or a visible emission.

(3) Control room operating log.

(a) Check concentration of sulfur dioxide entering and leaving the converter. Any unconverted sulfur dioxide will pass through the absorber to atmosphere.

(b) Check temperature of 98% absorber tower acid. If the acid temperature is considerably above 180°F, excess sulfur trioxide and acid mist can be discharged to atmosphere.

(c) Determine operating rates from log and compare with design capacity from permit system records. Operation at over-capacity can result in excessive emissions of sulfur dioxide and acid mist.

(4) Potential of the source to create a nusiance problem in terms of:

(a) Possible effects of sulfur dioxide and acid mist on people and property.

(b) Excessive emissions of sulfur dioxide during cold start-ups, upset conditions or overload operations.

(c) Excessive emissions of acid mist during oleum production or improper operation of absorber.

The inspector should attempt to relate tail gas concentrations and appearance to operating parameters during the time of his inspection. This information will be useful in interpreting causes of upsets or off-normal conditions leading to excessive discharge of air contaminants. Finally, it will be very useful for the inspector to be present during a start-up operation to obtain first hand information on optimum procedures for minimizing losses.

H. NATURE OF SOURCE PROBLEM - VINYL CHLORIDE MANUFACTURING

The manufacture of polyvinyl chloride plastics in the United States is second only to polyethylene production. As of 1967(8) there were nineteen vinyl chloride monomer plants having a capacity of 2.8 billion pounds, of which one billion pounds was based upon the use of acetylene. Predictions at that time were that the use of acetylene as a starting chemical would be phased out rapidly in favor of ethylene-based oxychlorination processes which are at the present time more attractive economically. Industry sources confirms that this indeed has occurred.

Over 80% of the chlorine production and 50% of the HCl production in the United States is consumed in the organic chlorination industry with a very high proportion of this quantity being used in vinyl chloride production.(9) There are strong economic reasons to recover and recycle as much of the chlorine and HCl as possible.

1. Nature of Air Pollution Problems

The manufacture of vinyl chloride monomer ($CH_2 = CHCl$) is based upon the chlorination and hydrochlorination of acetylene and/or ethylene. Although the air pollution potential is not great, the purging of inert gases such as nitrogen from the air used in oxychlorination processes can result in the loss of small quantities of unreacted chlorine, hydrogen chloride, acetylene, ethylene, vinyl chloride, partially oxidized hydrocarbons, and chlorinated side-reaction products.

These materials may be controlled by the use of caustic scrubbers, absorption units, and waste heat boilers.

An intermittent problem may result from the burn-off of accumulated carbon from the beds used in the cracking of ethylene dichloride to form vinyl chloride. Normally this operation is easily controlled but the discharge of products from incomplete combustion, including smoke, is at least possible.

The transfer and storage of chlorine, hydrogen chloride and vinyl chloride are usually completely closed operations, making any release of these compounds very unlikely.

I. PROCESS DESCRIPTION - VINYL CHLORIDE MANUFACTURING

1. Basic Reactions

Vinyl chloride ($CH_2 = CHCl$) is a colorless, flammable compound having an ethereal odor. It boils at -13.81°C and is stored under slight pressure to maintain the liquid state. Until recent years the principal manufacturing process used involved the hydrochlorination of acetylene(10) according to the following reaction:

$$CH = CH + HCl \xrightarrow{HgCl} 2\ CH_2 = CHCl$$

The reaction, which is exothermic, takes place over a mercuric chloride catalyst. In addition to the vinyl chloride product, the reactor gases contain small quantities of acetylene, HCl, and other organic addition products. Figure 7.7.5 shows a simplified schematic flow sheet of the process. The vent gases from the absorber are composed of about 90% inert gases and 10% acetylene. The relative quantity of these gases is very low.

The other important basic reactions leading to the production of vinyl chloride involve (1) the chlorination of ethylene to form ethylene dichloride (more properly 1,2 dichloroethane) followed by (2) the cracking of ethylene dichloride (EDC) to yield vinyl chloride and hydrogen chloride. These reactions are seen below:

$$CH_2 = CH_2 + Cl_2 \rightarrow CH_2Cl - CH_2Cl$$

$$CH_2Cl - CH_2Cl \xrightarrow{heat} CH_2 = CHCL + HCl$$

A first step at improving the economics of the acetylene and ethylene routes to vinyl chloride resulted in the so-called "balanced processes." One variation of such a process is shown in Figure 7.7.6. Although this flow sheet is considerably simplified, vent gases are similar to the basic acetylene process.

2. Current Manufacturing Practice

During the past few years there has been a rapid change in industry practice to adopt the oxychlorination process for manufacturing vinyl chloride.(11, 12, 13) In this process, ethylene, oxygen (almost always from air), and ethylene are the starting materials.

The hydrogen chloride resulting from the cracking of ethylene dichloride formed by the chlorination of ethylene is fed together with oxygen and ethylene to form additional ethylene dichloride. Thus, no acetylene is

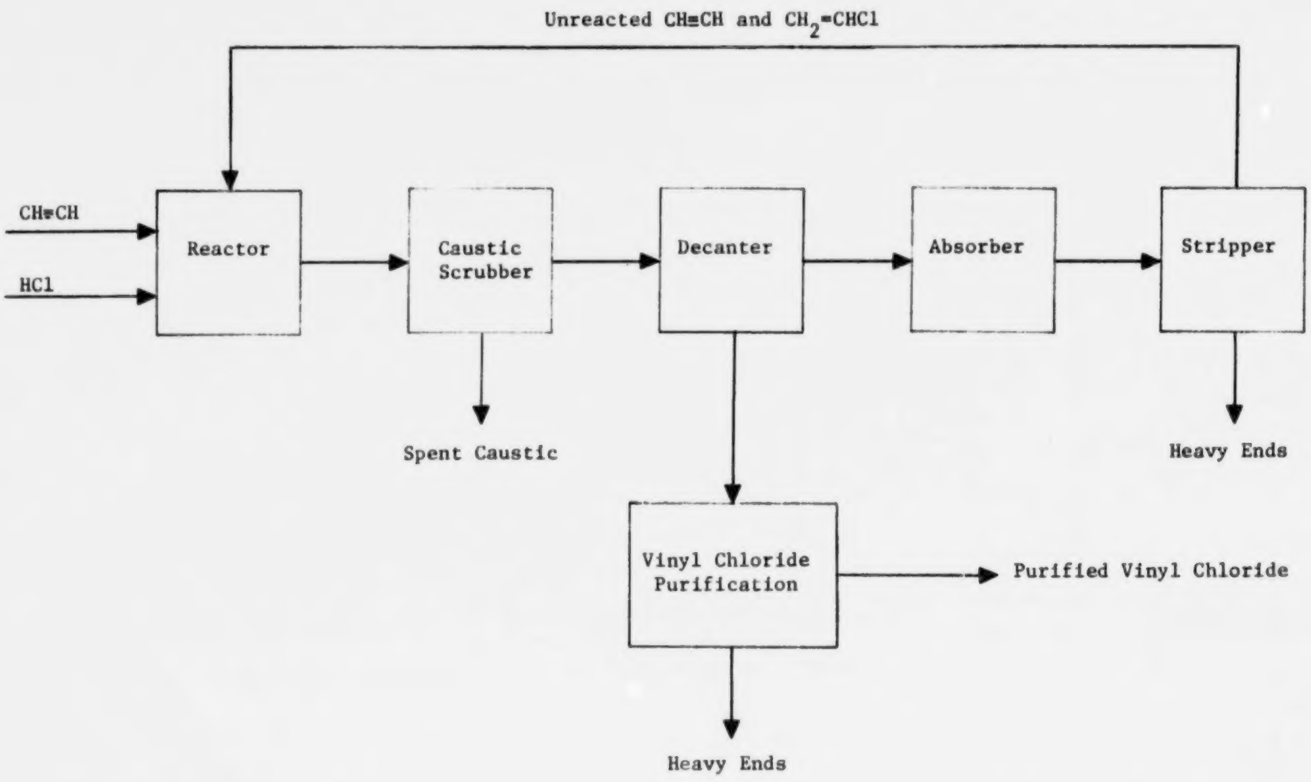

Unreacted CH≡CH and CH_2=CHCl
CH≡CH
HCl
Reactor
Caustic Scrubber
Decanter
Absorber
Stripper
Spent Caustic
Heavy Ends
Vinyl Chloride Purification
Purified Vinyl Chloride
Heavy Ends

Figure 7.7.5 MANUFACTURE OF VINYL CHLORIDE FROM ACETYLENE AND HYDROGEN CHLORIDE

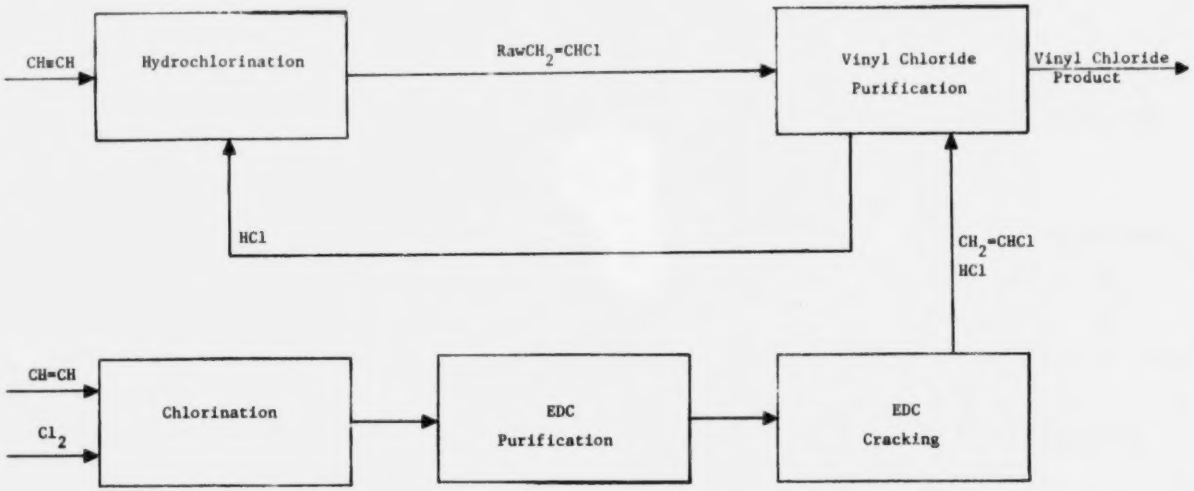

CH≡CH
Hydrochlorination
RawCH$_2$=CHCl
Vinyl Chloride Purification
Vinyl Chloride Product
HCl
CH$_2$=CHCl
HCl
CH=CH
Cl$_2$
Chlorination
EDC Purification
EDC Cracking

Figure 7.7.6 BALANCED PROCESS FOR VINYL CHLORIDE USING ACETYLENE AND ETHYLENE

needed to utilize the by-product hydrogen chloride. Figure 7.7.7 shows a schematic flowsheet of one approach to this process. In the United States pure ethylene is normally used as the starting material, although in Japan at least one producer utilizes a relatively impure mixed stream of ethylene and acetylene prepared from the on-stream cracking of naphtha.(14)

In the oxychlorination process the conversion efficiency of ethylene to vinyl chloride is estimated to be in the range 96-98%. By-products include unreacted feed materials, oxygenated compounds and carbon oxides. These materials plus any inert gases must be removed from the reactor gases prior to the ethylene dichloride cracking step. The non-condensibles may be vented directly to atmosphere or to some form of air pollution control equipment.

The ethylene dichloride following purification is cracked to form vinyl chloride and hydrogen chloride with the latter being separated and returned to the oxychlorination reactor. The cracking takes place at 450° - 650°C at elevated pressures, and is usually done over a catalyst. Some carbonization and tar formation takes place depositing these materials on the catalyst. These deposits must be burned off the cracking bed periodically in order to restore its effectiveness. Modern practice is to use a steam-moderated air oxidation process for the carbon burn-off. When carried out properly only carbon dioxide should be vented.

3. Control Methods

The principal air pollution problem in the vinyl chloride manufacturing process has to do with the purge gas venting taking place after the reactor stages and before the ethylene dichloride cracking step. Inert gases, mainly nitrogen, may be accompanied by unreacted ethylene and chlorine, hydrogen chloride, oxygenated organics, and carbon oxides.

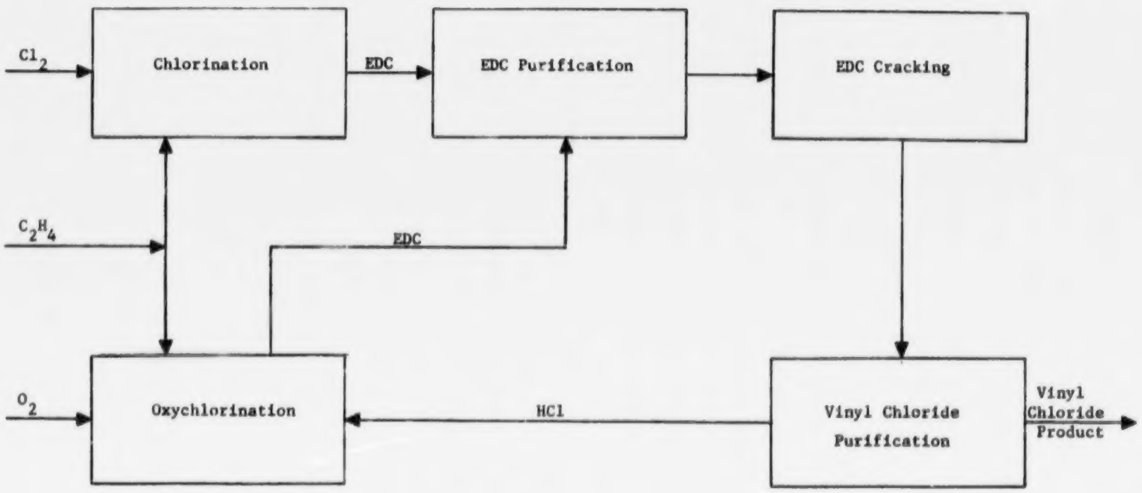

Cl_2
Chlorination
EDC
EDC Purification
EDC Cracking
C_2H_4
EDC
O_2
Oxychlorination
HCl
Vinyl Chloride Purification
Vinyl Chloride Product

Figure 7.7.7 OXYCHLORINATION PROCESS FOR MANUFACTURE OF VINYL CHLORIDE

In a well-controlled vinyl chloride plant, these vent gases are generally collected in a common manifold and treated by the following series of air pollution control measures: (1) caustic scrubbing of reactor vent gases; (2) combustion of oxidizable compounds in a waste heat boiler; and (3) caustic scrubbing of boiler vent gases to remove additional acid gases formed in the boiler.

Careful control of the waste heat boiler, usually by metering auxiliary fuel through a steam output rate actuated controller, is necessary to avoid smoke formation during any vent gas surges.

A lesser problem is associated with the vinyl chloride purification steps. Here, vinyl chloride is usually liquified by refrigeration to -20°C. Vent gases are discharged through a caustic scrubber.

Vinyl chloride is usually stored as a liquid in spherical pressurized containers. All transfer operations are accomplished using vapor return lines. The technology used is similar to that used for liquified petroleum gases. Routine losses are not expected.

J. INSPECTION POINTS - VINYL CHLORIDE MANUFACTURING

A well operated and controlled vinyl chloride monomer plant should result in practically no air pollution problems. However, should vent gases not be controlled properly, the release of smoke, odorous substances and property damaging acid gases is possible.

1. Environmental Surveillance

The greatest potential problem from a vinyl chloride plant is the release of acid gases, principally chlorine and hydrogen chloride. The hydrogen chloride particularly reacts with moisture in the air to form hydrochloric acid mist and vapor which has the potential for accelerating corrosion in metals, damaging paint, and degrading other surfaces and materials. When acid gas losses are suspected, the surrounding area should be examined for evidence of the type of damage just described. Test plates of susceptible materials may be used if necessary. The damage pattern, if any, should be correlated with wind direction. A wind rose (see Chapter 6, Section V, Odor Detection and Evaluation) obtained from a representatively located wind direction recorder is particularly useful.

Odors associated with partially oxidized organic substances and chlorinated hydrocarbons are possible. They should be evaluated and any complaints reviewed.

2. Plant Inspection

a. Interview

As seen from the description of the manufacturing process a wide variety of specific plant design features may be expected in vinyl chloride plants. Also they may be integrated with the production of other chlorinated hydrocarbons. Therefore, it is very important to obtain an exact description of the process used and the starting materials.

Specific inquiry should be made as to the number and location of process vents, the nature of vent gases, the procedure for collecting vent gases, and the specific control techniques and equipment used. The design objectives for caustic scrubbers should be obtained.

Plant management should be asked to describe procedures for controlling vent gases during upsets, including methods for preventing or minimizing smoke from afterburners or waste heat boilers.

b. Physical Inspection

The inspector should verify the placement of various items of equipment in the process, paying particular importance to the location and height of various vents. Determination should be made of the production rate as a percent of rated capacity, the specific materials being charged to the process, and whether operating conditions are representative of the normal situation.

It will be useful to inspect the plant at various times to observe start-up operations, catalyst burn-off, and raw materials and product transfer.

Should visible emissions or odors be detected as a result of plant operations, a specific determination of the associated operating conditions should be made.

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VIII. PRIMARY AND SECONDARY NON-FERROUS SMELTING AND REFINING

A. INTRODUCTION

The smelting and refining of non-ferrous metals are primarily concerned with the production of copper, lead, zinc and aluminum ingots and alloys. This activity is important from the standpoint of both the air pollutants emitted and the extensive production of these metals in the United States. Primary aluminum reduction is treated in Section XI of this chapter.

Copper, lead and zinc occur mainly as sulfides and are mined either in open pits or in underground operations.

Primary smelting refers to the extraction of the virgin metal from its original ore by crushing large quantities of ore-bearing rock, concentration of the resultant feed and application of pyrometallurgical processes such as roasting, melting and conversion. The operation may also include dross recovery. Since the percentage of the recoverable material is small, emissions of oxides of sulfur, fumes, dust and particulates are likely to be very great and difficult to control.

Secondary smelting and refining are concerned with the preparation and melting of scrap metal of known and unknown analysis, dross recovery and wire reclamation. The major metals of interest include copper-base alloys (brass, bronze and black copper), zinc, lead and aluminum. Emissions from melting operations include smoke, dust, fumes, oxides of sulfur, and fluxing and degreasing agents.

Refining refers to the removal of impurities necessary to produce an ingot or alloy of desired specification. Non-ferrous foundries, treated in Section IX of this chapter, involve sand-casting and are oriented to the production of consumer and industrial products.

Primary smelters usually constitute, large, difficult to control single sources of air pollution, are usually located outside of urban areas and can be significant sources of visible emissions and plant damage. Secondary smelters are commonly found in industrial and urban areas, close to sources of scrap and other raw materials generated by population centers. They are significant sources of pollution, as well as local public nuisance problems. Both industries employ similar equipment, although primary smelting involves a larger variety of processes.

B. DESCRIPTION OF SOURCE--PRIMARY SMELTING

The history of controlling emissions from non-ferrous smelters goes back to the middle of the 19th century. Developmental projects are still underway to find economic methods for further reducing sulfur oxide emissions from smelters. While SO_x is the major contaminant of interest from this source, particulate emissions inherent in the job of extracting any metal from its ore, is also a major problem although air pollution control techniques and efficient equipment are currently available.

National sulfur oxide emissions from non-ferrous smelters are estimated at almost 3,000,000 tons, based on an annual rate for the first half of 1969 and excluding sulfur oxides or byproducts from pyrite roasting and sulfur burning. Of this amount 852,900 tons of SO_x were recovered and 1,924,400 tons were emitted to the atmosphere.(1) Other commonalities of non-ferrous smelting include high temperature gas emissions at 1200°F to 2400°F, heavy dust and fume loading and lean sulfur oxides concentrations in the off-gases all of which make recovery difficult and economically questionable.

The Air Pollution Control Inspector, although not generally involved in the research and development projects associated with the overall problem of recovery of sulfur oxides, must be familiar with the basic processes, type and magnitude of emissions, state of the art of air pollution control methods and possible future changes in this technology.

1. Process Description

a. Copper

Before any of the pyrometallurgical processes (furnace and related operations) can begin, the feed must be prepared into a concentrate for economic recovery of copper. After initial crushing, the ore is fed to wet ball or rod mills where it is allowed to settle and is filtered. The resultant concentrate is mixed with copper precipitates obtained from leaching mine waste and oxidized ores. The concentrate contains between 70 and 85% copper and small quantities of direct smelting sulfides and oxide ores which also contain four to six percent copper.

Table 7.8.1(1) shows a typical analysis of a high quality concentrate. The concentrate has a free moisture content of 10 to 12 percent while the precipitant contains 15 to 30 percent water.

Table 7.8.1 Typical High Quality Concentrate Analysis

Constituent	Percent (dry basis)
Copper, Cu	27.5
Iron, Fe	24.5
Sulfur, S	31.5
Silica, SiO_2	11.0
Other	5.5

(SOURCE: ARTHUR G. MCKEE & CO., Reference 1)

The typical copper smelter in the United States uses a roaster, reverberatory furnace and converter in the sequence shown in Figure 7.8.1. Variations to the system shown in the flow diagram include predrying of the feed in rotary driers or multiple hearth dryers, or direct charging to a reverberatory furnace.

(1) Roasting

Wet concentrate is sprayed as a slurry or charged dry into a multiple hearth, or, in more modern plants, a fluid-bed roaster. Depending on the size of the roaster, the charge can be 200 to 1500 tons/day of feed plus silica fluxes. The roasting drives off the moisture and converts parts of the sulfur to sulfur dioxide and the iron to iron oxide. Roasting reduces the fuel requirements of the reverbatory furnace by about half. The concentration of SO_2 from multiple-hearth type roasters is about 7% while the concentration of SO_2 fluid-bed roasters is about 15%.(2) The operating temperatures for both systems is about 1200°F. The temperature of the dust-laden gases leaving the furnace is reduced by dilution air, water spray or heat exchangers to 600°F. Initial dust and fume control is achieved by use of settling chambers or mechanical collectors followed by electrostatic precipitators. The dust loading is between three and six percent of the feed, most of which is captured in the flues. The roaster gas then either goes to the stack or the sulfuric acid plant (Table 7.8.2(3)). The calcine from roasting is hot and dusty and

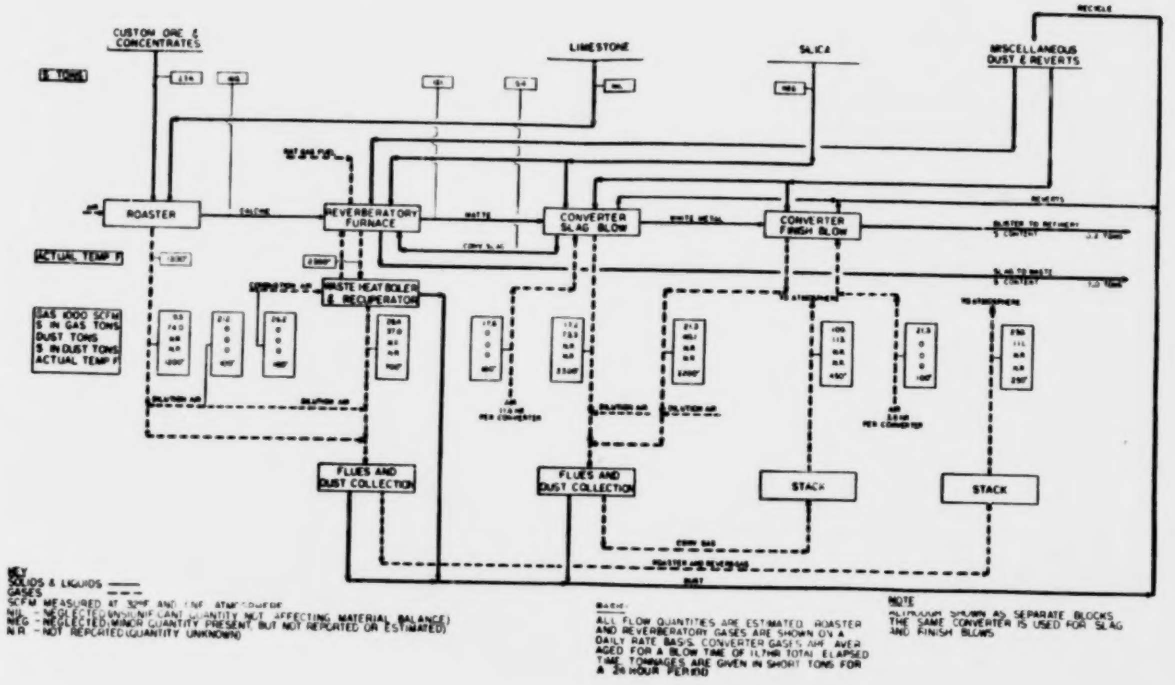
CUSTOM ORE & CONCENTRATES
LIMESTONE
SILICA
MISCELLANEOUS DUST & REVERTS
RECYCLE
S TONS
ACTUAL TEMP F
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
AIR
ROASTER
CALCINE
REVERBERATORY FURNACE
MATTE
CONV SLAG
CONVERTER SLAG BLOW
WHITE METAL
CONVERTER FINISH BLOW
REVERTS
BLISTER TO REFINERY
S CONTENT
SLAG TO WASTE
S CONTENT
WASTE HEAT BOILER & RECUPERATOR
DILUTION AIR
PER CONVERTER
TO ATMOSPHERE
FLUES AND DUST COLLECTION
STACK
CONV GAS
ROASTER AND REVERB GAS
DUST
KEY
SOLIDS & LIQUIDS
GASES
SCFM MEASURED AT 32°F AND 1 ATMOSPHERE
NIL - NEGLECTED(INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NEG - NEGLECTED(MINOR QUANTITY PRESENT, BUT NOT REPORTED OR ESTIMATED)
NR - NOT REPORTED(QUANTITY UNKNOWN)
BASIS:
ALL FLOW QUANTITIES ARE ESTIMATED. ROASTER AND REVERBERATORY GASES ARE SHOWN ON A DAILY RATE BASIS. CONVERTER GASES ARE AVERAGED FOR A BLOW TIME OF 11.7HR TOTAL ELAPSED TIME. TONNAGES ARE GIVEN IN SHORT TONS FOR A 24 HOUR PERIOD
NOTE
ALTHOUGH SHOWN AS SEPARATE BLOCKS THE SAME CONVERTER IS USED FOR SLAG AND FINISH BLOWS

Figure 7.8.1. FLOW DIAGRAM OF A TYPICAL COPPER SMELTER
(SOURCE: ARTHUR G. MCKEE & CO., Reference 1)

handling this material, which is charged to the reverberatory furnace, presents a dust control problem. Added to this problem is the introduction of the material captured in the primary dust collector to the charge of the reverbatory furnace.

Table 7.8.2.(3) EMISSIONS FROM COPPER ROASTERS, REVERBERATORY FURNACES, AND CONVERTERS[a]

	Waste Gas (m^3)	Raw Gas Dust Content (gm/m^3)	Raw Gas SO_2 Content %
Roasters	1300[b]	15	2-8
Reverberatory furnaces	2000[b]	4	-
Converters	10,000[c]	12	to 8

[a] Clean Air Guide 2101, Kommission Reinhaltung der Luft, Verein Deutscher Ingenieure, VDI--Verlag GmbH, Dusseldorf, West Germany, January 1960

[b] Per ton of concentrates

[c] Including extraneous air per ton of charge

(SOURCE: NELSON, Reference 3)

(2) Reverberatory Furnaces

The function of the reverberatory furnaces is to melt the calcine from roasting, green ore, recycled "flue dust" or converter slag to form matte--a mixture of cuprous and ferrous sulfides and slag. A slightly oxidizing atmosphere is maintained in the furnace by providing excess air above the requirements for theoretically complete combusion. Furnace sizes range from 22 feet x 96 feet to 38 feet x 125 feet and hold a molten batch 24 to 48 inches deep with a feed rate of 400 to 1100 tons/day. (See Figure 6.2.16, Fuel-Burning, Chapter 6, Section II.) The furnace operating temperature reaches 2400°F. This high temperature and large volume of the exhaust gas lends itself to heat recovery in waste-heat boilers for generation of steam and electrical power. The typical operating conditions from an oil or gas fired furnace are shown in Table 7.8.3.

Table 7.8.3. TYPICAL REVERBERATORY FURNACE OPERATING CONDITIONS

Furnace bath temperature	2400°F
Excess Air	1 - 4 percent
Furnace pressure	+0.1 in. of water
Dust load in offgas	2 - 5 grains per scf
Sulfur dioxide in offgas	0.5 - 3.5 percent

(SOURCE: ARTHUR G. MCKEE & CO., Reference 1)

Table 7.8.4 shows the off-gas composition at 2400°F based upon the feed (green feed or calcined feed) to the furnace; Table 7.8.5 gives the composition of the molten products from the reverberatory furnace.

Table 7.8.4. REVERBERATORY FURNACE OFF-GAS COMPOSITION

Component	Green Feed	Calcine Feed
Carbon Dioxide	8.4%	10.2%
Nitrogen	69.3%	71.0%
Oxygen	0.25 - 1.0%	0.25 - 1.0%
Water	18.8%	17.7%
Sulfur Dioxide	1.5 - 3.5%	.6 - 1.0%

(SOURCE: ARTHUR G. MCKEE & CO., Reference 1)

Table 7.8.5. COMPOSITION OF REVERBERATORY FURNACE MOLTEN PRODUCTS

Component	Matte	Slag
Copper	25 - 50%	0.4 - 0.7%
Iron	29 - 35%	34 - 40%
Silica	0.8 - 1.0%	35 - 40%
Sulfur	22 - 29%	1.0 - 1.5%

(SOURCE: ARTHUR G. MCKEE & CO., Reference 1)

Dust loading in the gases leaving the furnace is heavy. Up to 25%(4) of the dust is recovered by gravity in the balloon flues upstream of the waste heat boiler. This necessitates the use of feeders (screw or gravity) from the flues and hoppers to remove the dust for recycling. The smaller particle sizes are then exhausted to the electrical precipitator. The particulates from copper smelting operations are volatalized oxides, fumes of antimony, arsenic, zinc lead, bismuth, tellurium and selenium. A by-product of non-volatilized metals include nickel, cobalt, and precious metals which can be separately refined.

(3) Converters

Copper matte is transferred from the reverberatory furnaces to the converters in large ladles by overhead cranes. Converting is a batch process with three distinct phases of operation: charging, slag skimming and pouring. Air or air enriched with oxygen is blown into the furnace through tuyeres for oxidation. A temperature of 2250°F is maintained by the oxidation reaction without the requirement for additional fuel. Most converters in use are Pierce-Smith type cylindrical furnaces, 13 feet in diameter and 30 feet long with an average daily production of 135 tons of copper, depending on the grade of matte charged.

The process oxidizes and separates the iron and sulfur from the copper in the matte. The furnaces are operated in sequence so that the air/oxygen blowing will not occur at the same time to allow a fairly regular flow of SO_2 to the acid plant. The highest theoretical concentration of SO_2 occurs after the slag has been skimmed and the "white metal" or cuprous sulfide has been converted to copper.

Capturing the fume and off-gases from this type of furnace requires hooding similar to the equipment used on basic oxygen furnaces (see Section IV). The tighter the hood fits, the less dilute are the emissions of sulfur oxides to be controlled. The drawback is that temperatures at the hoods remain high which may damage the hoods and accompanying ductwork. Some experiments are being conducted with water cooled hoods in connection with waste heat boilers to reduce the temperature to 600°F between the converters and the electrostatic precipitators. The product of the converter is blister copper which is 99% pure and is either used in this form or further refined for anode production or other shapes.

Two approaches to copper production which have received considerable attention and which should be mentioned for possible future interest are continuous smelting and hydrometallurgy. Continuous smelting will likely replace the reverberatory furnace and converter with a single unit while hydrometallurgy will likely replace all of the conventional pyrometallurgical processes with electrolytic processes after the sulfide ore has been pretreated.

(4) Contaminants Emitted

Emissions from roasting, reverberatory furnaces and converters consist of dust, fumes and sulfur oxides.

Typical volumetric analyses of offgases are:(1)

Roasters	SO_2/SO_3-12%
Reverberatory furnaces	SO_2/SO_3-0.6%
Converters	SO_2/SO_3-5.0%

While perhaps not typical, some measured particulate concentrations from these operations are roasters 18-24 GR/SCF; reverberatory furnaces 0.55-6.0 GR/SCF; converters .55-3.0 GR/SCF.(4)

A common practice among plants that recover sulfur is to vent the gases released from the roaster and converter gases to sulfuric acid plants and to vent the reverberatory gases to the atmosphere because of the low SO_x content.

Without the imposition of air pollution control standards, economics would be the only criteria for the control of particulates and SO_x. The control of dust and fumes can be achieved by the use of dust control trains consisting of a mechanical separator, gravity separators and electrostatic precipitators. The recovery of oxides of sulfur is receiving a great deal of attention, not only in the smelter industry but from all processes where SO_x is generated. Acid plants and elemental sulfur recovery operations will come into increased use. The sulfuric acid production is discussed in Chemical Plants, Section VII.

b. Lead

Lead sulfide (or galena) is prepared similarly to copper sulfide concentrate. Lead mineral galena generally contains 55 to 70 percent lead; as much as 6.5 percent zinc; 0.5 to 4.0 percent copper; 13 to 18.5 percent sulfur; as much as 5.0 percent iron and silica, lime, cadmium, silver and gold; and arsenic in minor amounts.

Existing lead producing practices in the United States involve fundamentally identical operations: Sintering, reduction in blast furnaces and refining. While the processes are similar, different types of equipment can be employed. Figure 7.8.2(1) shows a flow chart for a lead smelting operation.

(1) Sintering

Sintering is the agglomeration of fine particles by partial fusion due to application of heat. Sintering is conducted to prepare the lead sulfide concentrate and involves a combination of roasting to remove the sulfur and sintering to form a strong porous mass suitable for reduction of the lead oxide in the blast furnace. Figure 7.8.3(1) is a flow diagram showing material components of a typical sintering operation.

Two types of sintering machines known as Dwight-Lloyd machines are in use. The older downdraft machine draws in large quantities of excess air diluting the SO_x concentration and requiring recirculation of the gases to bring the concentration up to 4-7% SO_2. The newer updraft machine draws in less outside air and does not dilute the concentration of SO_x. Recirculation is also used in this machine to further enrich the effluent for recovery as H_2SO_4.

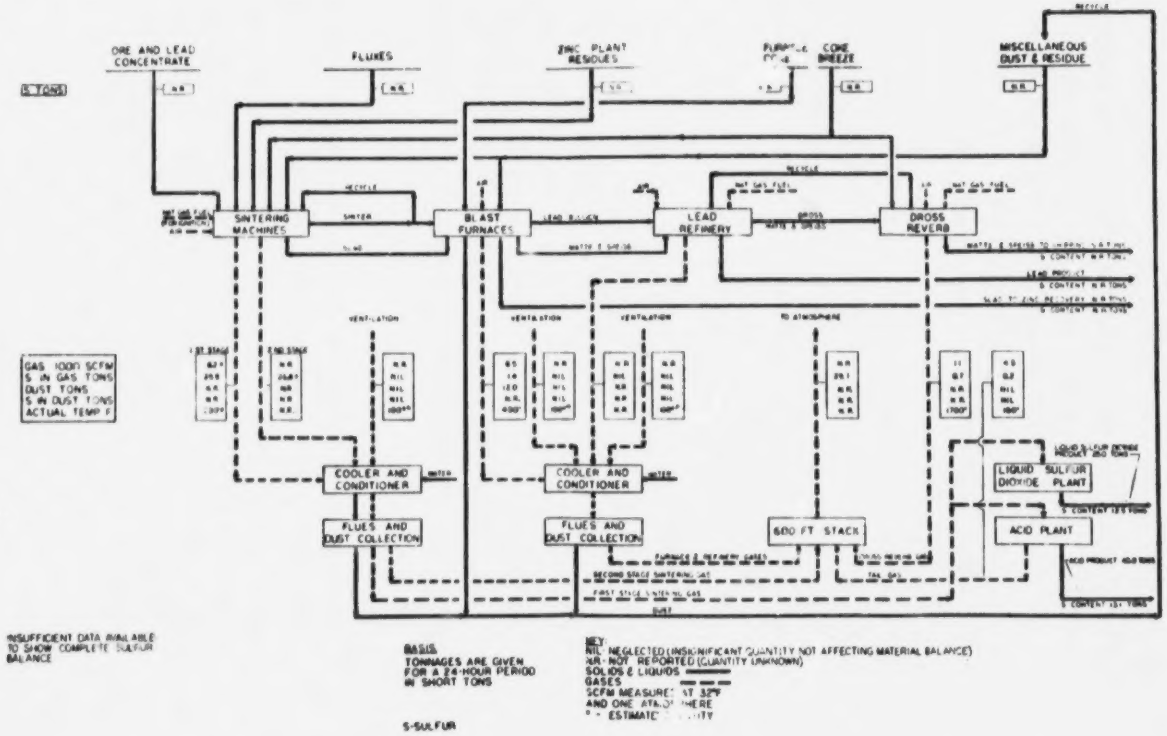
S TONS
ORE AND LEAD CONCENTRATE
FLUXES
ZINC PLANT RESIDUES
COKE BREEZE
MISCELLANEOUS DUST & RESIDUE
RECYCLE
SINTERING MACHINES
SINTER
SLAG
BLAST FURNACES
AIR
LEAD BULLION
MATTE & SPEISS
LEAD REFINERY
NAT GAS FUEL
DROSS
DROSS REVERB
MATTE & SPEISS TO SMELTING
LEAD PRODUCT
S CONTENT N.R TONS
SLAG TO ZINC RECOVERY N.R TONS
VENTILATION
TO ATMOSPHERE
1 ST STAGE
2 ND STAGE
GAS 1000 SCFM
S IN GAS TONS
DUST TONS
S IN DUST TONS
ACTUAL TEMP F
COOLER AND CONDITIONER
WATER
FLUES AND DUST COLLECTION
600 FT STACK
LIQUID SULFUR DIOXIDE PLANT
ACID PLANT
FURNACE & REFINERY GASES
SECOND STAGE SINTERING GAS
FIRST STAGE SINTERING GAS
TAIL GAS
DUST
INSUFFICIENT DATA AVAILABLE TO SHOW COMPLETE SULFUR BALANCE
BASIS
TONNAGES ARE GIVEN FOR A 24-HOUR PERIOD IN SHORT TONS
S-SULFUR
KEY:
NIL- NEGLECTED (INSIGNIFICANT QUANTITY NOT AFFECTING MATERIAL BALANCE)
NR- NOT REPORTED (QUANTITY UNKNOWN)
SOLIDS & LIQUIDS
GASES
SCFM MEASURED AT 32°F AND ONE ATMOSPHERE
* - ESTIMATED QUANTITY

Figure 7.8.2. FLOW CHART FOR A LEAD SMELTING OPERATION
(SOURCE: ARTHUR G. MCKEE & CO., Reference 1)

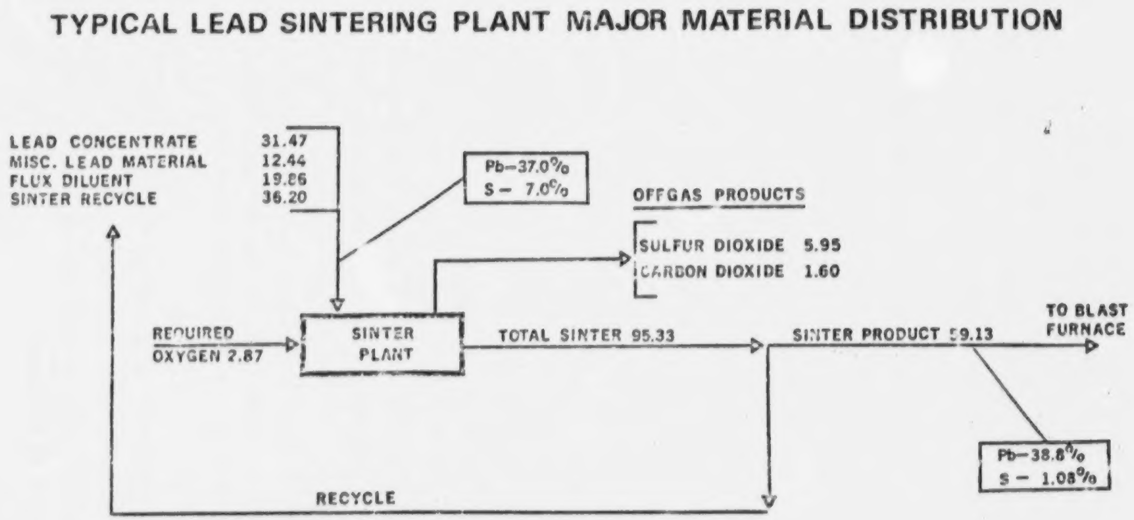
TYPICAL LEAD SINTERING PLANT MAJOR MATERIAL DISTRIBUTION
LEAD CONCENTRATE 31.47
MISC. LEAD MATERIAL 12.44
FLUX DILUENT 19.86
SINTER RECYCLE 36.20
Pb—37.0%
S – 7.0%
OFFGAS PRODUCTS
SULFUR DIOXIDE 5.95
CARBON DIOXIDE 1.60
REQUIRED OXYGEN 2.87
SINTER PLANT
TOTAL SINTER 95.33
SINTER PRODUCT 59.13
TO BLAST FURNACE
Pb—38.8%
S – 1.08%
RECYCLE

Figure 7.8.3. TYPICAL LEAD SINTERING PLANT MAJOR MATERIAL DISTRIBUTION
(SOURCE: ARTHUR G. MCKEE & CO., Reference 1)

Physically, the machines are conveyors made of gratebar pallets joined together to form an endless chain. They range in size from 3-1/2 x 22 feet to 10 x 103 feet. The wind box is located under the pallets or the downdraft machine and above the pallets on the updraft machine.

Both designs can be either single or two-stage operations. About 85% of the sulfur in the feed is removed during sintering, with 14% entering the slag and other solid by-products. The remaining one percent is released from the blast and dross furnaces. In a two-stage operation, 30 to 40% of the sulfur is removed during the first stage. The clinker is crushed and mixed with one to two percent coke and returned to the machine. Even in single-stage machines 40 to 60 percent of the calcine is recycled.

Feed to the sintering equipment is usually pelletized for ease in handling and ignition. Natural gas is used for ignition but the reaction of forming lead and other oxides maintains the necessary heat. Control to maintain temperatures below 1400°F is essential to preclude volatilization of metals in order to produce the proper clinker with 1 to 3-1/2% sulfur, and to maintain the grates. Limiting the sulfur in the feed to between 6-12% and using sulfide-free fluxes such as silica and limestone helps to keep the temperature within the desired limits.

As with most smelting operations the prime target of air pollution control is SO_x. However, some of the operations develop large quantities of dust and fumes, up to 20% of the feed in some sintering operations, which will be of concern to the air pollution control inspector. Economics of operation dictate that efficient dust and fume control be exercised due to the quantity of material entrained in the offgas. The captured material is recycled. The inspector must make sure that capture of the dust and fume is acceptable as well as cleaning the offgas in the air pollution control equipment. The offgas temperature varies between 250 and 600°F depending on the amount of excess air drawn into the system. Gas volumes are 100 to 220 SCFM per sq. ft. of bed area. Since baghouses are often used to collect the dust and fumes, the temperature is critical with regard to the filter material. Gas temperature and humidity are also important in electrostatic precipitator operations (see Section IV, Steel Mills).

(2) Blast Furnaces

Sinter, iron and coke are charged into the blast furnace where the lead oxide is reduced to lead. At the usual operating temperatures of 1000° to 1200°F (gas temperature), iron oxide and zinc oxide are not reduced to metals but, along with most of the sulfur present, leave the furnace in the slag. Since some zones of the furnace reach higher temperatures there is some distillation of lead oxide and zinc oxide. These materials along with dust and volatilized cadmium oxide are entrained in the exhaust gases. There is little SO_2 reported in the exhaust gases. Dust from the charge and fumes from the chemical reactions are entrained in the air blown through the tuyeres up through the charge. The chemical reactions are:

$PbO + CO + heat = Pb + CO_2$

$C + O_2 = CO_2 + Heat$

$C + CO_2 + Heat = 2CO$

Theoretical flue gas rates are 6000 to 14,000 SCFM varying with the size of the furnace. Blast air is between 5000 and 9000 SCFM. The actual gas volume to be handled from the furnace is 9 to 12 times the theoretical flow due primarily to the large volume of air which leaks in at the top of the furnace. The furnace gas, before dilution, contains 25 to 50 percent CO and may reach temperatures of 1400°F. The high volume of dilution air aids in the combustion of CO to CO_2 and serves to reduce the gas temperature to a resultant temperature of 150 to 250°F before entering the air pollution control equipment.

The blast furnace produces four liquids: lead bullion, matte, speiss (metallic arsenides) and slag. The lead bullion is separated by gravity and goes to the refining process. The matte and speiss go to the dross furnace for further lead recovery. The slag is removed separately and is either transported to a dump or is moved hot to fuming furnaces for recovery of lead and zinc.

Typical composition:(1)

Lead Bullion:	95% to 99% lead.
Matte:	44 to 62% Copper, 10 to 20% lead and up to 13% sulfur; up to 2% zinc and small amounts of iron and silica.

Speiss:	55 to 64% copper; up to 18% lead and traces of sulfur and aresenic; 1% zinc and 0.5% iron and silica
Slag:	High silica 10 to 20% zinc; up to 2% lead and 3% sulfur; some iron and calcium.

(3) Lead Refining

Lead refining produces high purity bullion (95 to 99%) as well as matte, speiss, and dross in operations employing reverberatory furnaces and refining kettles or pots. The products from the lead blast furnace are fed to a gas or oil-fired reverberatory furnace at about 1400°F with an oxidizing atmosphere. Dross forms over the surface of the batch which becomes a product to be processed in the dross reverberatory along with matte and speiss. The remaining dross, matte and speiss are skimmed from the dross reverberatory after optimum lead removal and are shipped to copper smelters for reclamation of copper, which may run from 44 to 62 percent. Figure 7.8.4(3) describes the complete cycle of lead smelting.

Refining kettles are used to bring the bullion to desired limits of antimony, zinc, arsenic, tin, etc. by the introduction of sodium hydroxide, sodium nitrate or sodium salts. Table 7.8.6(3) describes emission rates from a lead smelting operation. It indicates an absence of SO_2 emissions from reverberatory furnaces. However, the McKee study (1) indicates that sulfur can be added to both the reverberatory furnaces and the refining kettles which can cause the emission of as much as 0.2 percent of sulfur oxide for short periods after the addition of sulfur.

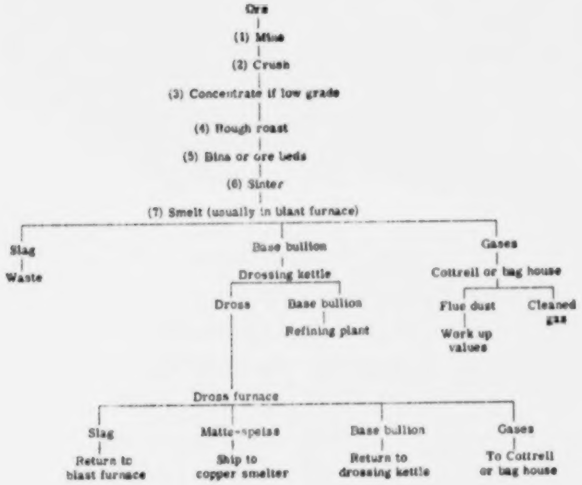
Ore
(1) Mine
(2) Crush
(3) Concentrate if low grade
(4) Rough roast
(5) Bins or ore beds
(6) Sinter
(7) Smelt (usually in blast furnace)
Slag
Waste
Base bullion
Drossing kettle
Dross
Base bullion
Refining plant
Gases
Cottrell or bag house
Flue dust
Work up values
Cleaned gas
Dross furnace
Slag
Return to blast furnace
Matte-speise
Ship to copper smelter
Base bullion
Return to drossing kettle
Gases
To Cottrell or bag house

Figure 7.8.4. USUAL TREATMENT OF A SULFIDE LEAD ORE (SOURCE: NELSON, Reference 3)

Table 7.8.6. EMISSIONS FROM LEAD SINTERING, BLAST FURNACES, AND REVERBERATORY FURNACES[a]

		Raw gas	
	Waste gas (m^3)	Dust content (gm/m^3)	SO_2 content (%)
Sintering	3000[b]	2-15	1.5-5
Blast furnaces	15,000-50,000[c]	5-15	—
Reverberatory furnaces	100-500[d]	3-20	—

[a] Clean Air Guide 2285, Kommission Reinhaltung der Luft, Verein Deutscher Ingenieure, VDI—Verlag GmbH, Dusseldorf, West Germany, September, 1961.

[b] Per ton of sinter.

[c] Per ton of coke.

[d] Per ton of charge.

(SOURCE: NELSON, Reference 3)

(4) Additional Equipment and Operations

Since the by-products of lead smelting contain recoverable amounts of cadmium and zinc oxide some plants also process this material. Cadmium roasters, slag fuming furnaces and deleading kilns are used in these instances. Emissions of sulfur oxides from these processes are minor relative to the total operation but dust and fume emissions can be significant. The inspector should observe these operations to determine their compliance with the appropriate regulation.

(5) Contaminants Emitted

While lead smelting operations are responsible for a smaller volume of sulfur oxide emissions than from copper smelting the amounts are still appreciable. In addition, a substantial quantity of dust and fumes are generated in these operations which may be more significant than gases or liquid aerosols.

Levels of concentration of emissions vary. Gaps in data exist especially for dust and fume emissions.

Sintering machines will emit between 0.8 to 1.8 percent sulfur oxides by volume and from 5 to 20 percent of the feed as dust and fumes. Blast furnace emissions of sulfur oxides will range between 0.01 to 0.25 percent. Dust and fume emissions from smaller secondary smelting operation using cupolas, sampled by the Los Angeles County Air Pollution District, indicate a dust loading of 12.3 gr/SCF.(6) Reverberatory furnaces also emit relatively small quantities of sulfur oxides usually less than 0.05 percent, while dust loading can be about 6 gr/SCF.

As in copper smelting, dust and fume collection is achieved by combinations of mechanical separators with baghouses or precipitators.

Control of sulfur oxide emissions is variable since some of the processes emit lean mixtures. In most instances, emissions of SO_x from sintering operations are sufficiently rich for use in H_2SO_4 plants which act, in effect, as air pollution control systems.

c. Zinc

Two principal "raw" materials are used in the production of zinc. ZnS (sphalesite) which is separated by selective flotation to a concentrate that contains 60% Zn and the slag from lead blast furnaces where zinc is recovered as an impurity in fuming furnaces. In both cases it is necessary to form dense zinc oxide for extraction of the zinc by either pyroreduction and distillation or electrolytic precipitation.

In the pyroreduction sequence, the concentrate is either roasted and sintered in two separate processes or in a single process in the sintering machine. Figure 7.8.5(1) shows a typical operational sequence of a zinc retort plant. The potential air contaminants emitted from these operations are SO_x and zinc oxide fume. The latter, however, is a requirement for zinc production and will probably be well controlled.

(1) Roasting

Roasting oxidizes about 93 to 97% of the sulfur in the concentrate to produce zinc oxide calcines. The calcines contains 2 to 3-1/2% sulfur as sulfide and sulfate in a completely roasted batch.

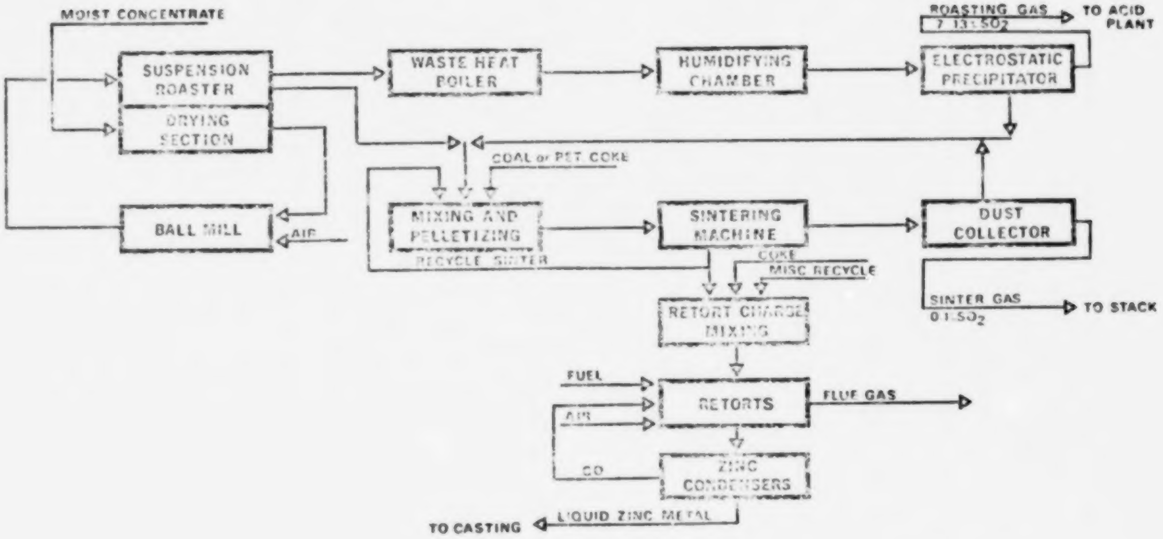
MOIST CONCENTRATE
SUSPENSION ROASTER
DRYING SECTION
BALL MILL
AIR
WASTE HEAT BOILER
HUMIDIFYING CHAMBER
ELECTROSTATIC PRECIPITATOR
ROASTING GAS
7-13% SO2
TO ACID PLANT
COAL or PET COKE
MIXING AND PELLETIZING
RECYCLE SINTER
SINTERING MACHINE
DUST COLLECTOR
SINTER GAS
0.1% SO2
TO STACK
COKE
MISC RECYCLE
RETORT CHARGE MIXING
FUEL
AIR
RETORTS
FLUE GAS
CO
ZINC CONDENSERS
LIQUID ZINC METAL
TO CASTING

Figure 7.8.5. TYPICAL ZINC RETORT PLANT FLOW DIAGRAM(1)
(SOURCE: ARTHUR G. MCKEE & CO., Reference 1)

A number of roasting methods are in use in the United States. Table 7.8.7 gives an overview of names, operating conditions and expected dust and SO_2 concentrations in the offgas. Dust collectors usually employed in roasting operations are electrostatic precipitators. However, large quantities of dust settle in the flues and waste heat boilers. The resultant dust free offgas, which contains from 4.5 to 12% SO_2, is usually ducted to an H_2SO_4 acid plant for collection or to tall stacks.

Table 7.8.7. TYPICAL ZINC ROASTING OPERATIONS

TYPE OF ROASTER	OPERATING TEMP. F	FEED CAPACITY TON/DAY	DUST IN OFFGAS % OF FEED	OFFGAS SO_2%
Multihearth	1,200-1,350	50-120	5-15	4.5-6.5
Multihearth (2)	1,600-1,650	250	5-15	4.5-6.5
Ropp (3)	1,200	40-50	5	0.7-1.0
Fluid bed (4)	1,640	140-225	70-80	7-8
Fluid bed (2)	1,650	240-350	75-85	10-12
Fluid bed (Lurgi)	1,700	240	50	9-10
Suspension	1,800	120-350	50	8-12
Fluid column	1,900	225	17-18	11-12

(1) Dead roast except where noted otherwise (complete roasting using exothermic heat of reaction of sulfur with O_2).

(2) First stage is a partial roast in multihearth, second stage is a dry-feed dead roast in fluid bed.

(3) Partial roast.

(4) Slurry feed.

(SOURCE: ARTHUR G. MCKEE & CO., Reference 1)

(2) Sintering

Where roasting is used to oxidize the sulfur in the concentrate, sintering is employed to agglomerate the calcine. Double-pass sintering is used in the absence of roasting operations. Table 7.8.8 describes typical sintering operations with the resulting dust and SO_2 content.

Table 7.8.8. TYPICAL ZINC SINTERING OPERATIONS

Case:	1	2	3
New feed material	calcine	calcine	concentrate
Total charge capacity tons per day	240-300	400-450	550-600
Machine size, ft	3.5 x 45	6 x 97	12 x 168
Fuel added to feed, %	6 - 7	10-11	0 - 2
Total sulfur in new feed, %	8	2	31
Recycle, % of new feed	35-75	40-70	80
Dust in offgas, % of feed	5	5 - 7	5 - 10
Offgas SO_2 content, %	1.5-2.0	0.1	1.7-2.4

(SOURCE: ARTHUR G. MCKEE & CO., Reference 1)

Downdraft machines are used in all sintering operations in the zinc industry (as opposed to both updraft and downdraft in lead--see description of sintering machines in Part B,2,a). The product is a hard pourous clinker which is mixed with coke breeze to reduce the oxide that may be present in retorts and condensers.

The dust from the process ranges from 5 to 10% of the feed and is collected for recycling or treated for lead and calcine recovery. The sulfur content in the offgas is low, 0.1 to 2.0%, but can be enriched to 6.0 to 6.5% by recycling to make it economically feasible for collection in an acid plant. However, these gases are usually vented through tall stacks.

(3) Zinc Extraction

The steps of roasting, sintering and calcining (when performed) are necessary for the preparation of the material for either pyroreduction or electrolysis for extraction of zinc from zinc oxide.

1. In pyroreduction the sinter is mixed with coke breeze and processed in vertical retorts, horizontal retorts (the Belgian retort process), electric arc furnaces or blast furnaces. The vapor formed is condensed as either liquid or solid powder. The Imperial Smelting Process, not in use in the United States, uses a blast furnace to vaporize zinc which is condensed by a shower of molten lead. The zinc dissolves in the lead and floats to the top of the container outside of the condenser where it overflows and is cooled to produce 98% pure zinc.
2. The electrolytic zinc process produces high purity zinc by using calcine in H_2SO_4 solution to remove impurities and a lead anode and aluminum cathode to accomplish the electrolysis. The zinc is hand-stripped from the cathode, remelted and poured into slabs for treatment.(3)

(4) Contaminants Emitted

Tables 7.8.7(1) and 7.8.8(1) show typical concentrations of dust and SO_2 from zinc roasting and sintering operations. Of the 15 primary zinc smelters in the United States, nine recover sulfur from the offgases and these only from roasters. The sulfur is recovered as sulfuric acid.

Dust and fumes which escape the process or are collected in inefficient or undersized dust collectors are also a potentially serious problem from this industry. Large quantities of dust are transmitted in the roaster and sintering offgases and unless capture and recovery is excellent, significant quantities of small particles can be emitted to the atmosphere since nearly all of the particulates are $<10\mu$.(3)

Most dust and fume collection is achieved in baghouses and electrostatic precipitators. The problem in these areas is pickup of particulates at the generation points and their handling systems.

2. Inspection Points--Primary Smelting and Refining

The emission of sulfur oxides is the major contribution to air pollution from non-ferrous smelters. Particulates, especially specific particulates such as lead, are receiving increasing attention.

a. Environmental Observations

When economics prohibit the capture of SO_x in smelters, tall stacks are used to disperse the large quantities of sulfur oxides emitted. Even with tall stacks, meteorological conditions and topography can cause the plumes to dip into areas adjacent to the smelters causing the classic SO_2 damage to plant life and respiratory difficulties. Particulates (dust, fumes and sulfuric acid mist) also can cause reduced visibility when meteorological conditions are conducive to the accumulation of air pollution.

Section II, Kraft Pulp Mills, describes methods of investigating the results of excessive emissions of sulfur oxides. The assistance of residents and workers in adjacent areas is important since, in effect, 24-hour surveillances can be achieved.

b. Observations of the Exterior of Smelters

Most processes in smelters vent to one or more tall stacks which theoretically allow the sulfur oxides to disperse to concentrations below those which would cause damage to plants, animals or buildings. Under some weather conditions the plume which is visible from the stack will bend into areas adjacent to the smelter. The inspector should observe the plume during as many changes in plant operation as possible in order to correlate changes in opacity with differing operations.

Dust and fume emissions from any pyrometallurigical processes and materials handling can be spotted from outside of the facility if the inspector is familiar with the plant layout. Specific operations of concern include the loading and discharging of sintering machines, charging working furnaces and pouring from furnaces. Zinc distillation furnaces, if not properly vented with close fitting high inlet velocity hoods, can lose fume which can be detected from roof monitors and windows of the building housing the processes.

Large sections of smelter property may be unpaved and material may be stored in large piles without cover. These points, common to many industries, should be noted and reported to plant management as high potential dust sources.

c. In-Plant Observations

Non-ferrous smelters comprise sizeable operations usually spread over many acres of ground and are frequently the subject of many studies and legal actions. The inspector must present himself to plant management with a clear picture of the air pollution control regulations he is obligated to enforce. He must obtain cooperation of management in order to thoroughly understand the operations. He should devote sufficient time to observing the basic operations to learn the cycles, time periods of day when the various phases of the operations occur and sequence of operations and identifying the management personnel responsible for the various operations. The McKee report(1) shows a flow diagram for many of the non-ferrous smelting operations in the United States. This is an excellent starting point for an inspector, but it must be emphasized that it is only a starting point. Also, the inspector should become very familiar with the maintenance practices of the company. Maintaining the control equipment is probably the most important aspect of controlling emissions and is visually given last priority.

Acid processes are treated in Section VII of this chapter. They currently present the principal method of controlling SO_2 emissions from smelters. The inspector should become familiar with the venting system and be able to determine when the acid plant is by-passed and the sulfur oxides are vented to atmosphere.

Dust and fume control systems are a necessary part of smelter operations. In addition to air pollution control requirements, large quantities of dust must be separated from the process gases and returned to the process. Smelter offgases must be cleaned before processing in the sulfuric acid plants. The dust removal equipment consists of cyclone and other mechanical separators for large particle size dust, and baghouses and electrostatic precipitators for condensed fume and small, $< 10\,\mu$, dust particles.

C. NATURE OF SOURCE-SECONDARY SMELTERS

As a class, secondary smelters and refiners reclaim metals from scrap, drosses and slag. Operations and equipment for brass and bronze, lead, zinc, and aluminum are described in this section. Smoke, dust, fumes, sulfur oxides, fluxing and degreasing agents are typically emitted.

Large copper secondary smelters employ many of the same operations used in primary smelting with the exception of roasting. Precious metals are also recovered from electrolytic refining slimes at both primary and secondary copper smelters.

1. Process Description--General

A variety of metal alloys are produced in several basic types of furnaces. Reverberatory furnaces are used in the secondary smelting and refining of copper bearing alloys, aluminum and lead; blast furnaces or cupolas are used in copper and lead production; pot furnaces, crucibles and electrical induction furnaces are used for various refining processes in all non-ferrous operations. Zinc production alone has unique furnace requirements for secondary refining. This process requires retorts and condensers and holding furnaces for some refining processes.

a. Brass and Bronze

The basic steps in producing brass and bronze ingot in secondary smelters are:(5)

- Materials Preparation
  - Mechanical Methods
    - Hand Sorting
    - Stripping
    - Shredding
    - Magnetizing
    - Briquetting

  - Pyrometallurgical Methods
    - Sweating
    - Burning (Insulation Removal)
    - Drying
    - Blast furnace or Cupola (melting or oxide reduction)
  - Hydrometallurgical Methods--flotation process
- Ingot Production
  - Reverberatory Furnaces
  - Rotary Furnaces
  - Crucible Furnaces

While not all of the steps or equipment involved in the total process emit air contaminants, the inspector should be familiar with the total cycle. In all brass and bronze production the primary air pollution control problem is the emission of zinc oxide during melting and pouring to produce the ingot. This naturally is a function of the zinc in the metal to be produced and in the metal that makes up the charge to the furnaces. Table 7.8.9(5) shows the nominal specifications of copper base alloys commonly produced in the United States. As the zinc and lead content increases, melting operations become more critical relative to potential zinc oxide and lead oxide emissions. Other likely contaminants from these processes are dust and smoke from fuel combustion and from grease and oil present in the scrap used as charge material.

This industry scavenges material to be refined into ingot to meet the specification shown previously. The source of this material is the scrap salvage industry. Table 7.8.10(5) describes the major types of industrial and military scrap which become the raw material charged to the secondary brass smelter.

Table 7.8.9. NOMINAL CHEMICAL SPECIFICATIONS FOR BBII STANDARD ALLOYS

Alloy No.	Classification	Cu, %	Sn, %	Pb, %	Zn, %	Fe, %	Al, %	Ni, %	Si, %	Mn, %
1A	Tin bronze	88.0	10.0		2.0					
1B	Tin bronze	88.0	8.0		4.0					
2A	Leaded tin bronze	88.0	6.0	1.5	4.0					
2B	Leaded tin bronze	87.0	8.0	1.0	4.0					
2C	Leaded tin bronze	87.0	10.0	1.0	2.0					
3A	High-lead tin bronze	80.0	10.0	10.0						
3B	High-lead tin bronze	83.0	7.0	7.0	3.0					
3C	High-lead tin bronze	85.0	5.0	9.0	1.0					
3D	High-lead tin bronze	78.0	7.0	15.0						
3E	High-lead tin bronze	71.0	5.0	24.0						
4A	Leaded red brass	85.0	5.0	5.0	5.0					
4B	Leaded red brass	83.0	4.0	6.0	7.0					
5A	Leaded semi-red brass	81.0	3.0	7.0	9.0					
5B	Leaded semi-red brass	76.0	2.5	6.5	15.0					
6A	Leaded yellow brass	72.0	1.0	3.0	24.0					
6B	Leaded yellow brass	67.0	1.0	3.0	29.0					
6C	Leaded yellow brass	61.0	1.0	1.0	37.0					
7A	Manganese bronze	59.0	1.0	1.0	37.0	1.0	0.6			0.5
8A	Hi-strength mang. bronze	57.5			39.0	1.0	1.0			1.5
8B	Hi-strength mang. bronze	64.0			24.0	3.0	5.0			3.5
8C	Hi-strength mang. bronze	64.0			24.0	3.0	5.0			3.5
9A	Aluminum bronze	88.0				3.0	9.0			
9B	Aluminum bronze	89.0				1.0	10.0			
9C	Aluminum bronze	85.0				4.0	11.0	2.0		0.5
9D	Aluminum bronze	81.0				4.0	11.0	4.0		3.0
10A	Leaded nickel brass	57.0	2.0	9.0	20.0			12.0		
10B	Leaded nickel brass	60.0	3.0	5.0	16.0			16.0		
11A	Leaded nickel bronze	64.0	4.0	4.0	8.0			20.0		
11B	Leaded nickel bronze	66.5	5.0	1.5	2.0			25.0		
12A	Silicon bronze	88.0			5.0	1.5			4.0	1.5
12B	Silicon brass	82.0			14.0				4.0	

(SOURCE: CUFFE AND SCHWARTZ, Reference 5)

(1) Blast Furnaces and Cupolas

The blast furnace is an economical method of recovering copper from low grade scrap and slag. The material is charged through the top of the furnace with varying amounts of coke and limestone. Blast air is blown through the tuyeres at the bottom of the furnace.

By its nature, the blast furnace uses large quantities of air for combustion which creates a significant air pollution control

Table 7.8.10. TYPES OF COPPER-BEARING SCRAP

No.	Designation
1.	No. 1 copper wire
2.	No. 2 copper wire
3.	No. 1 heavy copper
4.	Mixed heavy copper
5.	Light copper
6.	Composition or red brass
7.	Red brass composition turnings
8.	Genuine babbitt-lined brass bushings
9.	High-grade, low-lead bronze solids
10.	Bronze papermill wire cloth
11.	High-lead bronze solids and borings
12.	Machinery or hard red brass solids
13.	Unlined standard red car boxes (clean journals)
14.	Lined standard red car boxes (lined journals)
15.	Cocks and faucets
16.	Mixed brass screens
17.	Yellow brass scrap
18.	Yellow brass castings
19.	Old rolled brass
20.	New brass clippings
21.	Brass shell cases without primers
22.	Brass shell cases with primers
23.	Brass small arms and rifle shells, clean fired
24.	Brass small arms and rifle shells, clean muffled (popped)
25.	Yellow brass primer
26.	Brass pipe
27.	Yellow brass rod turnings
28.	Yellow brass rod ends
29.	Yellow brass turnings
30.	Mixed unsweated auto radiators
31.	Admiralty brass condenser tubes
32.	Aluminum brass condenser tubes
33.	Muntz metal tubes
34.	Plated rolled brass
35.	Manganese bronze solids
36.	New cupro-nickel clippings and solids
37.	Old cupro-nickel solids
38.	Soldered cupro-nickel solids
39.	Cupro-nickel turnings and borings
40.	Miscellaneous nickel copper and nickel-copper-iron scrap
41.	New monel clippings and solids
42.	Monel rods and forgings
43.	Old monel sheet and solids
44.	Soldered monel sheet and solids
45.	Soldered monel wire, screen, and cloth
46.	New monel wire, screen, and cloth
47.	Monel castings
48.	Monel turnings and borings
49.	Mixed nickel silver clippings
50.	New nickel silver clippings and solids
51.	New segregated nickel silver clippings
52.	Old nickel silver
53.	Nickel silver castings
54.	Nickel silver turnings

(SOURCE: CUFFE AND SCHWARTZ, Reference 5) problem. Depending upon local air pollution control agency requirements, high efficiency scrubbers, baghouses and electrostatic precipitators, with primary separators for the removal of larger size particles, are used to control emissions. The baghouse has proven to be an excellent control device for cupola operations, if properly sized. As important as the dust removal system is, the design of the fume pick-up system should include good indraft velocity at the furnace charging door and hooding over the metal pouring spout.

The blast furnace or cupola is usually operated 24 hours per day with continuous slag pouring and intermittent metal pouring. Observation by the inspector should include furnace startup; at least for one hour's operation to determine if excessive smoke and fume escape during charging; inspection of the hoods and ductwork to determine if they are in good repair and if the efficiency of dust pickup has degraded. The operation of the air pollution control equipment, depending on the type used, must also be monitored.

The physical location of the dust and fume controls relative to the furnace may make observations of both control systems difficult, necessitating a two-man inspection. Efficiency of the air pollution control equipment can only be accurately checked by stack analysis. The inspector can, however, note gross changes in efficiency by comparing differences in opacities of emissions under different operating conditions.

Other preparational operations which can cause emissions are sweating, drying and burning. The removal of insulation by burning is covered in the section on incineration. Sweating to remove solder and other low melting point alloys can cause smoke and particulate emissions, depending upon the material being processed. The inspector should observe the precleaning or other precautions taken to assure minimum emissions from this operation. He should recommend the use of incinerators or scrubbers if a large volume operation is involved.

Drying chips require the use of afterburners or incinerators since the removal of oil by volatalization with resultant generation of opaque smoke and oil mists is involved. It will be obvious from the heavy emissions of smoke and mists that the afterburner is not in use, or is defective.

(2) Ingot Production--Reverberatory Furnaces

The basic furnace in a brass secondary smelter is the reverberatory furnace. It is usually gas or oil fired and can be either of the open hearth or rotary type, operating between 2300°F to 2600°F. In the production of brass and bronze ingot the inspector must be aware of the time periods of the operation during which most of the fume is generated, the condition of the material charged (oily or greasy) and the operation of the air pollution control system. The critical periods are charging either "raw" material or zinc slabs, to reach the desired specification, oxygen blowing if used, and pouring. Dense clouds of condensed fume or black smoke can occur due to charging of oily scrap. These emissions may be of such magnitude that the fume pickup system may not be able to handle the volume. The same is true during air or oxygen blowing. Pouring, which can take 1 to 3 hours, also generates large quantities of fume. The inspector should observe these operations for time and opacity. It is doubtful if any sizeable brass reverberatory furnace can meet time and opacity standards without a well designed air pollution control system.

The operation of other types of furnaces that may be found in a smelter, i.e., crucible and induction furnaces are described in Section IX of this chapter.

Quantitative and qualitative emissions from secondary brass smelting operations are shown in the following tables.(5)

Table 7.8.11. ROTARY FURNACE PARTICULATE EMISSIONS--TEST A

Cycle	Length, hr	Emissions, furnace[a]		Baghouse outlet[b]	
		lb/hr	Cycle total, lb	lb/hr	Total, lb
Charge[c]	6.50	30.05	195		
Refine	6.80	42.75	291		
Pour	1.28	9.54	12		
Total	14.58		498	1.78	25.9

[a] Furnace emission factor: 29.9 lb/ton.

[b] Collection efficiency: 94.8 percent.

[c] Total charge: 33,334 lb. Alloy produced: BBII Alloy No. 4A; 85-5-5-5.

(SOURCE: CUFFE AND SCHWARTZ, Reference 5)

Test A

A heat of red brass 85-5-5-5 (copper, zinc, tin, lead) was made in a 17-1/2 -ton-rated rotary furnace. A total of 33,334 pounds of scrap and 500 pounds of flux were charged to the furnace during the 6.5-hour charging period. Air blowing, slagging, and heating were performed during the 6.8-hour refining cycle. The pouring cycle lasted 1.3 hours.

During this test, only the 17-1/2-ton rotary furnace was operating. Inlet samples were collected during each period. A single sample was taken at the baghouse outlet over the entire heat. The exhaust system captured an estimated 90 to 95 percent of the particulate generated at the furnace.

Table 7.8.12. REVERBERATORY FURNACE PARTICULATE EMISSIONS -TEST C

Cycle	Length, hr	Emissions, furnace[a]		Baghouse outlet[b]	
		lb/hr	Cycle total, lb	lb/hr	Total, lb
Charge[c]	6.73	194.2	1.308		
Refine	9.30	159.3	1.482		
Pour	3.53	12.8	45		
Total	19.56		2.835	3.32	64.8

[a] Furnace emission factor: 53.7 lb/ton.

[b] Collection efficiency: 97.7 percent.

[c] Total charge: 105,500 lb. Alloy produced: BBII Alloy No. 4A, 85-5-5-5.

Test C (SOURCE: CUFFE AND SCHWARTZ, Reference 5)

A heat of 85-5-5-5 red brass was made in a 100-ton reverberatory furnace. A total of 105,000 pounds of metal was charged to the furnace over a period of 6.7 hours. Oxygen was supplied to the burners for 5.3 of these hours to increase the melting rate. During a 9.3-hour refining period there was intermittent air blowing, and 500 pounds of fluxes were added. Pouring took 3.5 hours.

This air pollution control system serves three 100-ton reverberatory furnaces. The gases pass through a common spray chamber and then through a set of U-tube radiation coolers. From this point, the 450° F to 650° F gases are mixed with bleed-in air, go through the baghouse and a 75-horsepower fan, and pass to the stack. The 16-compartment shaker-type baghouse is fitted with heat-set Orlon bags. The total filter area is 7,360 square feet and the rated capacity is 19,000 cfm at 220° F. The design filter ratio, with one compartment out for cleaning, is 2.75/1.

Measured gas temperature at the baghouse inlet cycled between 200° F and 220° F. The measured gas volume averaged 15,000 scfm (70° F). Baghouse pressure drop varied from 4 to 5 inches of water.

One inlet sample was taken during each of these three furnace periods: charging, refining, and pouring. A continuous baghouse outlet sample was taken over the entire heat.

Table 7.8.13. CUPOLA PARTICULATE EMISSIONS--TEST E[a]

	Inlet		Outlet	
Sample	gr/scf	lb/hr	gr/scf	lb/hr
E-1	0.68	216	0.027	8.38
E-2			0.030	9.25
E-3			0.020	6.38
Average	0.68	216	0.026	8.00

[a] Charging rate: 5900 lb/hr. Collection efficiency: 96.4 percent. Furnace emission factor: 73.2 lb/ton.

Test E

At the system described in Test A, samples were taken while only the cupola was in operation. The cupola was charging at 20-minute intervals at the rate of 5,900 pounds per hour, including coke and flux.

Gas temperature at the baghouse was 145° F to 200° F and the volume was 44,000 scfm. The filter ratio was 2.11/1.

(SOURCE: CUFFE AND SCHWARTZ, Reference 5)

b. Lead

Secondary lead operations produce lead alloys and oxides employing reverberatory furnaces, pot furnaces, cupolas and the Barton Process for oxides. Sweating operations are also used to recover lead and other low melting alloys.

(1) Reverberatory Furnaces

Battery plates, dross and slag are melted in direct gas or oil fired reverberatory furnaces for lead reclamation (Table 7.8.14). The operation of the furnace is "tight" to allow admission of as little air as possible in order to maintain the furnace temperature of 2300°F. The furnace is recharged at regular intervals as the mass of the charge becomes fluid. About 10 to 12 pounds of metal are produced per squart foot of hearth area.(6) The furnace is tapped at regular intervals and is kept in continuous operation.

Table 7.8.14. CHEMICAL REQUIREMENTS FOR LEAD[a]
(ASTM Standards, Part 2, 1958)

	Corroding lead	Chemical lead	Acid-copper lead	Common desilverized lead
Silver, max %	0.0015	0.020	0.002	0.002
Silver, min. %		0.002		
Copper, max %	0.0015	0.080	0.080	0.0025
Copper, min. %		0.040	0.040	
Silver and copper together, max %	0.0025		0.040	
Arsenic, antimony, and tin together, max %	0.002	0.002	0.002	0.005
Zinc, max %	0.001	0.001	0.001	0.002
Iron, max %	0.002	0.002	0.002	0.002
Bismuth, max %	0.050	0.005	0.025	0.150
Lead (by difference), min. %	99.94	99.90	99.90	99.85

[a] Corroding lead is a designation used in the trade for many years to describe lead refined to a high degree of purity.

Chemical lead is a term used in the trade to describe the undesilverized lead produced from Southeastern Missouri ores.

Acid-copper lead is made by adding copper to fully refined lead.

Common desilverized lead is a designation used to describe fully refined desilverized lead.

(SOURCE: NANCE, et al., Reference 6)

The operation of a lead reverberatory furnace produces smoke and fumes by the nature of the operation. It is therefore necessary that an adequate air pollution control system be a part of the furnace design. The inspector must observe the charging and pouring operation to determine the collection efficiency of the fume pickup system since these are periods of heavy emission production. During the melting phase of the operation some smoke and fume escaping from the doors and other openings may occur due to the low negative pressure in the furnace. Indrafts at the hoods over these openings should be high enough to prevent the escape of puffs or continuous streams of fume. Baghouses are usually used to collect the particulates from lead refining operations. Table 7.8.15(6) describes the operating characteristics of an exhaust system and baghouse on a lead reverberatory furnace. In addition to dust and fumes, emissions of sulfur oxides are emitted. Stack analysis should be requested to determine the extent of these emissions. The requirements of the individual agency will govern the necessity for additional SO_x controls.

(2) Blast and Cupola Furnaces

These furnaces are similar to those used in grey iron foundries in physical appearance. They are used to produce lead from dross, oxide and reverberatory slags using a mixture of cast iron and limestone to form slag and coke for heating and reduction. The furnace is charged through a door near its top and blast air is blown in through tuyeres near the bottom. This is a continuous operation with the lead being discharged in a continuous tap and the slag being tapped intermittently. The tuyere air, as it is forced through the furnace, picks up dust and fumes which are usually vented to a baghouse. The furnace operates at between 1200°F and 1300°F and produces large volumes of CO, which must be burned to CO_2, and particulates. A high inlet velocity at all openings is required to prevent the escape of dust and fumes. The inspector should observe a light off and at least an hour of the operating cycle to determine that the air pollution control system is functioning properly. In a properly controlled operation, the system should be tight with no appreciable escape of smoke or fume from the furnace during any phase of its operation.

Table 7.8.15. DUST AND FUME EMISSIONS FROM A SECONDARY LEAD-SMELTING FURNACE(6)

Test No.	1	2
Furnace data		
Type of furnace	Reverberatory	Blast
Fuel used	Natural gas	Coke
Material charged	Battery groups	Battery groups, dross, slag
Process weight, lb/hr	2,500	2,670
Control equipment data		
Type of control equipment	Sectioned tubular baghouse[a]	Sectioned tubular baghouse[a]
Filter material	Dacron	Dacron
Filter area, ft^2	16,000	16,000
Filter velocity, fpm at 327°F	0.98	0.98
Dust and fume data		
Gas flow rate, scfm		
Furnace outlet	3,060	2,170
Baghouse outlet	10,400[b]	13,000[b]
Gas temperature, °F		
Furnace outlet	951	500
Baghouse outlet	327	175
Concentration, gr/scf		
Furnace outlet	4.98	12.3
Baghouse outlet	0.013	0.035
Dust and fume emission, lb/hr		
Furnace outlet	130.5	229
Baghouse outlet	1.2	3.9
Baghouse efficiency, %	99.1	98.3
Baghouse catch, wt %		
Particle size 0 to 1 μ	13.3	13.3
1 to 2	45.2	45.2
2 to 3	19.1	19.1
3 to 4	14.0	14.0
4 to 16	8.4	8.4
Sulfur compounds as SO$_2$, vol %		
Baghouse outlet	0.104	0.03

[a] The same baghouse alternately serves the reverberatory furnace and the blast furnace.

[b] Dilution air admitted to cool gas stream.

(SOURCE: NANCE, et al., Reference 6)

(3) Pot Furnaces

Pot furnaces range in capacity from 1 to 50 tons(6) and are used to alloy and refine lead. These furnaces should be hooded and vented to air pollution control equipment to meet both air pollution regulations and industrial hygiene requirements. Emissions can occur when drying dross to remove as much lead as possible by introducing sawdust; adding sulfur and agitating to reduce copper; or adding aluminum to reduce copper, antimony and nickle. The resultant slag is then skimmed from the pot. Hooding must be properly designed to pickup the fume and smoke generated by these actions. A special application is the production of lead oxide for battery lead, red lead and paint by the Barton Process. Lead at 700°F to 900°F is agitated by paddles while air is drawn through the molten metal. The resultant lead oxide is exhausted to a baghouse where the condensed fume is captured. This process is "closed" and should not emit appreciable fume.

c. Zinc

The reclamation of zinc in secondary smelting operations is performed by vaporizing or oxidation. The products from secondary zinc smelting are zinc, zinc oxide, and powdered zinc. Some zinc is also recovered in sweating operations described previously in this section.

The processes to reduce zinc oxide to metallic zinc uses powdered dross, collected zinc oxide condensed fume and contaminated zinc oxide from zinc plants all mixed with powdered coke and water to form a paste. The material is then charged to retorts for treating by the Belgian Retort Process. The retorts are arranged in banks and are heated externally by either gas or oil fired burners. The operating cycle is usually 24 hours with 65 to 70% of the zinc in the charge recovered with the remaining charge recycled. Temperatures on the outside of the retorts reach 2,550°F. The temperature of the charge is slowly brought up to 2,280°F. A carbcn dioxide rich atmosphere in the retorts actually reduces the zinc where it is condensed in the cooler, 780° to 1,020°F condenser section. Tapping of the zinc begins after about 8 hours. Figure 7.8.6(6) shows a cross section of a single Belgian retort furnace.

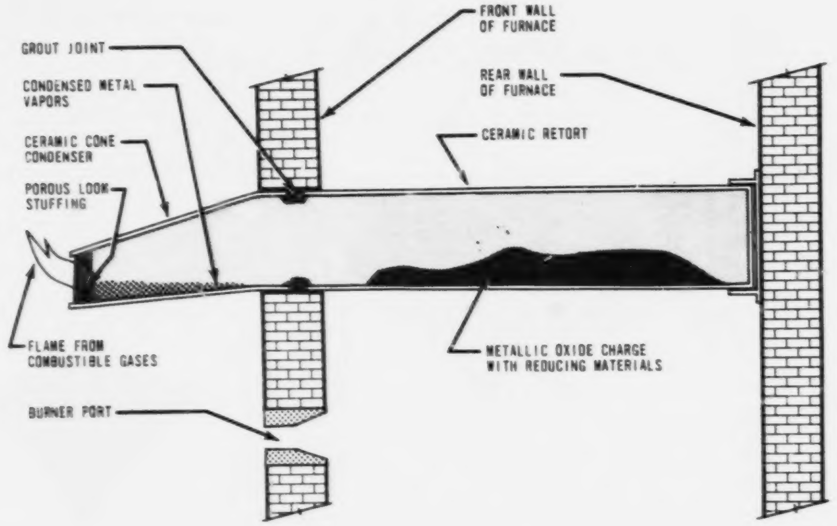
FRONT WALL OF FURNACE
GROUT JOINT
CONDENSED METAL VAPORS
REAR WALL OF FURNACE
CERAMIC CONE CONDENSER
CERAMIC RETORT
POROUS LOOM STUFFING
FLAME FROM COMBUSTIBLE GASES
METALLIC OXIDE CHARGE WITH REDUCING MATERIALS
BURNER PORT

Figure 7.8.6. DIAGRAM SHOWING ONE BANK OF A BELGIAN RETORT FURNACE
(SOURCE: NANCE, et al., Reference 6)

Distillation furnaces can produce zinc, zinc oxide or zinc powder using molten zinc as the charge. The distillation type retort furnace shown in Figure 7.8.7[(6)] is charged with molten zinc from a pot furnace. The retort is externally heated, vaporizing the zinc. The condenser is under positive pressure to prevent the zinc vapors from being oxidized while they condense. If zinc oxide is to be manufactured the zinc vapor goes through an orifice where it is mixed with air for oxidation. When the condenser is used it is vented through an opening called a speise hole. Here the zinc vapor burns and must be captured by a special hood provided for this purpose.

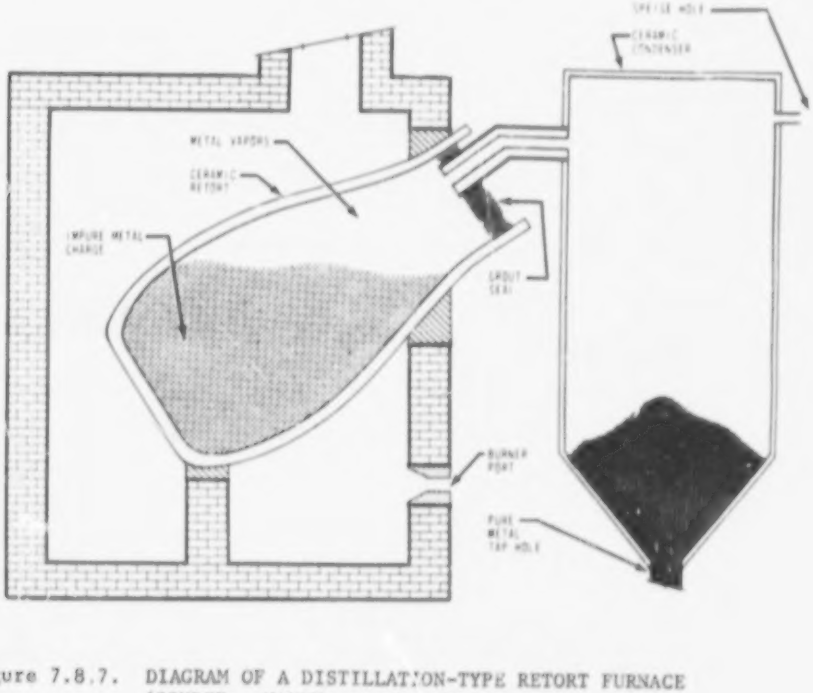
SPEISE HOLE
CERAMIC CONDENSER
METAL VAPORS
CERAMIC RETORT
IMPURE METAL CHARGE
GROUT SEAL
BURNER PORT
PURE METAL TAP HOLE

Figure 7.8.7. DIAGRAM OF A DISTILLATION-TYPE RETORT FURNACE
(SOURCE: NANCE, et al., Reference 6)

A second procedure employed to produce either pure zinc (99.99%) and pure oxide (99.95%) is conducted in a muffle furnace (Figure 7.8.8[(6)]). This system can handle scrap metal directly in its zinc feed well and sweating section. The furnace is heated by gas or oil firing with the products of combustion passing over the zinc feed well after heating the vaporizing section to 2,500°F. Molten zinc is formed in the condenser and maintained at about 900°F. When zinc oxide is to be formed, the vapors go through an orifice at the top of the first chamber and are mixed with air. The resultant zinc oxide is exhausted to a baghouse where it is collected.

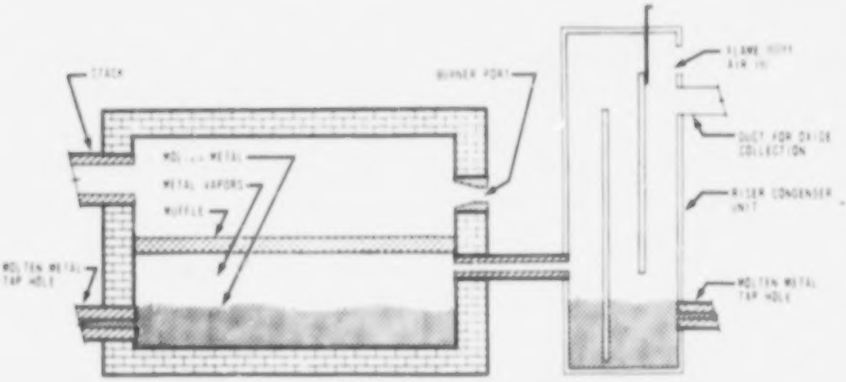
STACK
BURNER PORT
MOLTEN METAL
METAL VAPORS
MUFFLE
MOLTEN METAL TAP HOLE
FLAME PORT AIR IN
DUCT FOR OXIDE COLLECTION
RISER CONDENSER UNIT
MOLTEN METAL TAP HOLE

Figure 7.8.8. DIAGRAM OF A MUFFLE FURNACE AND CONDENSER (SOURCE: NANCE, *et al.*, Reference 6)

The inspector must become familiar with the operating procedure of the particular plant and the equipment. Every operation can have significant modifications to its equipment which can make it unique. Capture of condensed oxide fume or smoke from any opening in the aforementioned systems is the primary consideration. Air pollution control field personnel must physically check all phases of operation of these types of furnaces to make certain that the systems are tight and have minimal leaks.

d. Aluminum

Aluminum refining operations encompass many of the processes described in brass and bronze refining. Principal operations are chip drying, sweating, and pyrometallurgical refining.

Pit and crucible furnace operations are described in the section on foundries. This subsection will emphasize reverberatory furnaces since chip drying and sweating have been treated.

Reverberatory furnaces for aluminum refining range in capacity from 3,000 pounds to 50 tons and over. These are usually gas or oil fired and are continuously operated in large facilities. As in most metallurgical processes the production is batch, that is there is a charging phase, a working and fluxing phase and pouring. A heat can vary in length from 4 to 72 hours. The furnace is used to melt varied types of scrap and usually has a well where chips and other thin section scrap is charged into a molten bath. Figure 7.8.9(6) shows a 20-ton aluminum reverberatory furnace with a fume collection hood over the well.

In order to prevent burning of thin-walled sections that may be charged to the furnace, a heel of metal is required. This heel is formed by melting heavy pieces of scrap or ingot prior to the introduction of the lighter material.

The major air pollution control problem from aluminum refining operations arises from the fluxing and degreasing necessary to bring the melt to the specification required. Large quantities of solid

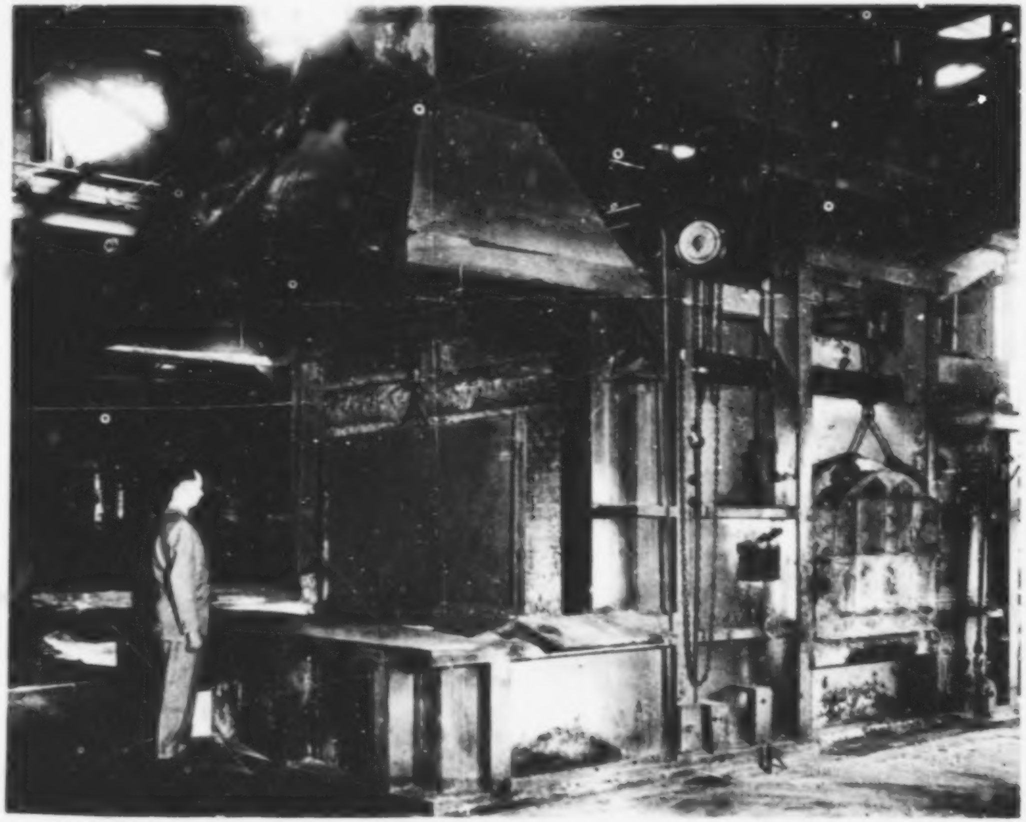

Figure 7.8.9. A 20-TON ALUMINUM-MELTING REVERBATORY FURNACE WITH CHARGING WELL HOOD, AARON FERRER & SONS, INC., LOS ANGELES, CALIFORNIA (SOURCE: NANCE, *et al.*, Reference 6)

fluxes, as much as 1/3 the weight of the aluminum scrap charged,(6) may be required to prevent oxidation and gas absorption. Fluxes that cause dense emissions are those used for degreasing and magnesium reduction. Chlorine gas and aluminum fluride are commonly used for magnesium reduction and cause the most extensive emissions.

The inspector should become completely familiar with the furnace operating cycle. He should observe the type of scrap charged to the furnace to determine if smoke and other particulates from the melting of dirty scrap are likely to occur. He should know the type and quantity of fluxes used. The Air Pollution Engineering Manual can be used as a reference on fluxing operations.

2. Inspection Points--Secondary Smelting and Refining

Secondary smelters are usually located in areas zoned for heavy industry so that the likelihood of nuisance complaints from these operations may not be great. Odors also are not generally attributed to secondary smelters but there can be significant quantities of dust created by some of the operations. Some copper refining operations can emit SO_2, although usually below the odor threshold of 1.0-5.0 ppm.

a. Environmental Observations

Dust and particulate fallout from metal preparation may be the most pronounced problems in areas adjacent to secondary smelters. These include mechanical shredding and size reduction, sweating and incineration. Relatively large dust particles and fly ash may be emitted from these operations and settle near the company in question.

b. Observation of the Exterior of the Secondary Smelter

Most of the processes of concern in secondary smelting and refining require heat to complete the operation. Usually one or more stacks are employed to vent the products of combustion or air pollution control system effluents. The inspector can pinpoint the stack or roof monitor emitting excessive smoke, dust or fumes and work backwards to the process or equipment responsible for the emissions. The color, opacity and length of plume can be of help in determining the source of the problem. Incinerators used for copper wire reclamation will emit dense black smoke if overloaded or if the auxiliary fuel is not in use. Sweat furnaces will do the same if the afterburner is not in operation. If a baghouse has torn bags it may appear to be burning if it is a push-through type; if the baghouse is a pull-through type the opacity of emissions from the stack can be over 50% when they would otherwise be near 0%.

c. The Physical Inspection

After obtaining the necessary data from the outside of the plant, the inspector should contact plant management to make the inplant inspection. If the inspector is completely familiar with the plant he can inform the operator which process caused the problem. If he is not familiar with the operation he should describe the color and opacity of the emissions and try to determine their origin. Determination of the equipment responsible for the emissions can present a problem in plants where many processes are vented to one stack. A plant survey should be one of the first requirements for an inspector who is new to an area.

During furnace inspections it is necessary to observe:

- Charging operations
  - Type and quantity of material charges
- Working or fluxing operations
  - Type and quantity of flux added
- Pouring operations
- Fuel being used

Mechanical inspection of equipment should include:

- Repair of furnace and doors for leaks
- Repair of hoods and ductwork
  - Pickup efficiency
- Effectiveness of air pollution control equipment

The inspector can make qualitative judgments of dust and fume emissions but he may have to rely on stack tests for quantitative results. These tests should not be limited to the stack. There are times when emissions from charging doors, hearths or from pouring can be very significant if not properly hooded and vented to an air pollution control system.

Figure 7.8.10(5) is a convenient scale showing the boiling, pouring and melting points of metals and alloys.

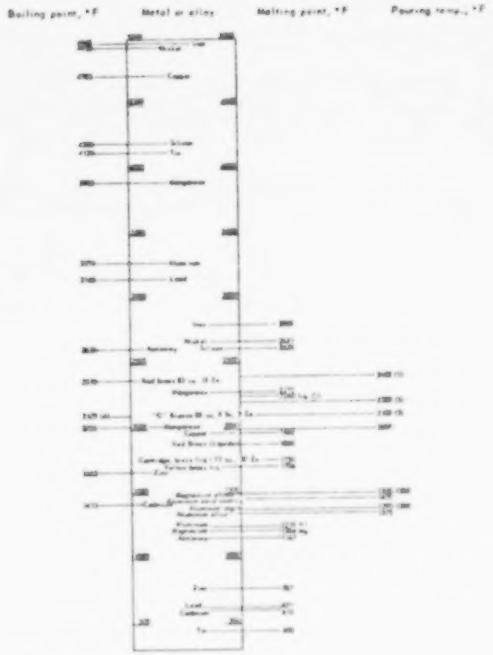

Figure 7.8.10. BOILING, POURING, AND MELTING POINTS OF METALS AND ALLOYS (SOURCE: CUFFE AND SCHWARTZ, Reference 5)

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6. Nance, J. T., W. F. Hammond, and K. D. Luedtke. Lead Refining. G. Thomas. Zinc Melting. H. Simon. Aluminum. In: Air Pollution Engineering Manual, J. A. Danielson (ed.). Cincinnati, DHEW, PHS, National Center for Air Pollution Control and the Los Angeles County Air Pollution Control District. P.H.S. No. 999-AP-40. 1967.

IX. FERROUS AND NON-FERROUS FOUNDRIES

A. DESCRIPTION OF SOURCES

The products of the ferrous and non-ferrous metallurgical industries are oriented to consumer or industrial use while smelters and refiners, dealt with in other sections of this chapter, provide alloys in ingot form to be used by the foundries.

While furnaces and melting practices have long been treated as major sources of air pollution from foundries, other operations also contribute. Among these are core making, sand handling, grinding, buffing and plating. Melting operations produce smoke and condensed fumes while the other operations produce dust, mists, organic gases and vapors.

B. GREY IRON FOUNDRIES

Ferrous foundries depend upon the cupola for the economical production of large quantities of grey iron. Electric furnaces and small reverberatory furnaces are also used in some specialty shops. Grey iron foundries have core making facilities, sand handling equipment and shakeout systems which are described under non-ferrous foundries below. The cupola is the oldest and still the most universally used furnace for the production of grey iron and a large contributor to air contaminants if not adequately controlled.

1. Process Description

A cupola is a firebrick-lined vertical cylindrical steel shell, approximately 27" to 108" in diameter, supported on structural steel legs. Air is supplied through a windbox and tuyeres (Figure 7.9.1) by either positive displacement blowers, centrifugal blowers or fan type blowers. As in blast furnaces, air is the largest single constituent

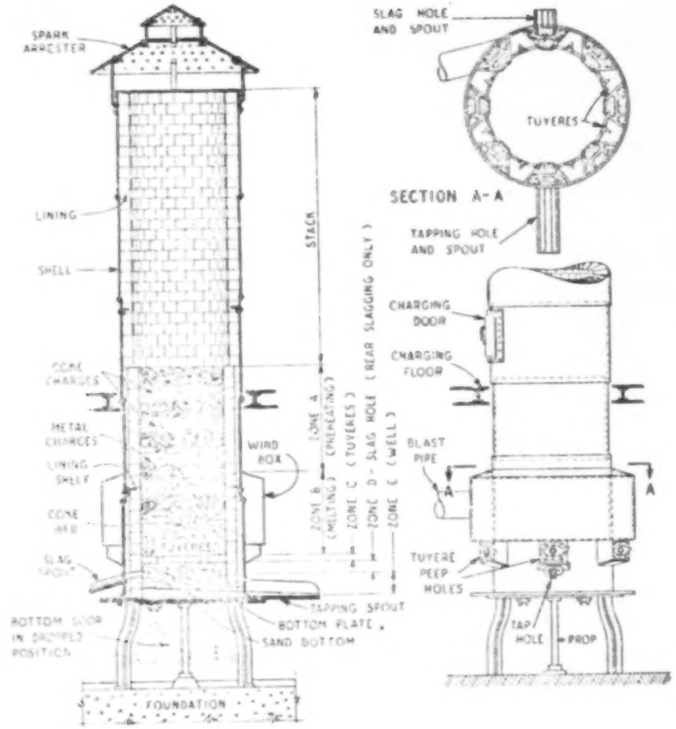
SPARK ARRESTER
LINING
SHELL
STACK
COKE CHARGES
METAL CHARGES
LINING SHELF
COKE BED
SLAG SPOUT
WIND BOX
ZONE A (PREHEATING)
ZONE B (MELTING)
ZONE C (TUYERES)
ZONE D - SLAG HOLE (REAR SLAGGING ONLY)
ZONE E (WELL)
TUYERES
TAPPING SPOUT
BOTTOM PLATE
SAND BOTTOM
BOTTOM DOOR IN DROPPED POSITION
FOUNDATION
SLAG HOLE AND SPOUT
TUYERES
SECTION A-A
TAPPING HOLE AND SPOUT
CHARGING DOOR
CHARGING FLOOR
BLAST PIPE
A
A
TUYERE PEEP HOLES
TAP HOLE
PROP

Figure 7.9.1. THE CUPOLA IN DETAIL (SOURCE: AIR POLLUTION ENGINEERING MANUAL)

of the heat, its weight being dependent on the size of the furnace and the metal to be melted. Some foundries recycle waste heat from the cupola to preheat the combustion air as an economy measure.

Preparation of a cupola for melting consists of preparing the bottom by securing the bottom drop door, placing a layer of sand over the door to prevent heat damage, closing the tap and slag holes and charging coke for the bed. The bed is ignited and allowed to burn through. The charges of coke, flux (limestone, fluorspar and soda ash) and metal (pig iron, scrap and steel) are placed in alternate layers up to the charge door which is 16' to 22' above the bottom. The blast is then turned on and melting begins. Charging continues until the desired tonnage has been melted after which the air is shut off and the furnace bottom is dropped allowing the remaining charges to fall on to the foundry floor. This material is recharged during the next operating cycle. Table 7.9.1 is a compilation of general operating conditions for cupolas describing capacities, physical characteristics and air/fuel requirements for all common cupola sizes.

Grey iron cupolas emit dust, fumes, smoke, gases (including about one pound of SO_2 per ton of metal melted), and oil vapors. Combustion-related contaminants and dust are picked up by the high velocity air stream forced through the charge. Considerable testing has been done by the Los Angeles County Air Pollution Control District for dust and fumes from cupolas. Table 7.9.2 shows the results of some of these tests. Oil mist and smoke in cupola exhaust gases are due largely to oil and grease contamination of the scrap metal charged to the furnace. Large volumes of CO are formed from the combustion of the coke. A typical analyses of exhaust gases(1) is CO_2-12.2%, CO-11.2%, O_2-0.4% and N_2-76.2%.

Table 7.9.1. GENERAL RECOMMENDATIONS FOR OPERATING WHITING CUPOLAS (SOURCE: BUREAU OF MINES, Reference 2)

(Practical Hints in Cupola Operation, No. 237-R, Whiting Corporation, Harvey, Illinois)

Cupola size	Shell diameter, in.	Min. thickness of inner lining, in.	Diameter inside lining, in.[a]	Area inside lining, in.^{2}	Melting rate, tons/hr, with iron/coke (also bed) ratios of				Bed coke height above tuyeres[b], in.	Coke and iron charges, lb					Limestone, lb	Air through tuyeres, cfm	Suggested blower selection[c]	
											Iron							
					6	8	10	12		Coke	6/1	8/1	10/1	12/1			cfm	Discharge pressure, oz
0	27	4-1/2	18	254	3/4	1			25 to 34	20	120	160			4	570	640	8
1	32	4-1/2	23	415	1	1-1/2			36 to 42	35	210	280			7	940	1,040	16
2	36	4-1/2	27	572	1-1/4	2-1/4			36 to 42	45	270	360			9	1,290	1,410	16
2-1/2	41	7	27	572	1-3/4	2-1/8			36 to 42	45	270	360			9	1,290	1,415	16
3	46	7	32	804	2-1/2	3-1/4	4		40 to 46	65	390	520	650		13	1,810	2,000	16
3-1/2	51	7	37	1,075	3-1/4	4-1/4	5-1/4		40 to 46	85	510	680	850		17	2,420	2,700	16 to 20
4	56	7	42	1,385	4	5-1/2	7		42 to 45	110	660	880	1,110		22	3,100	3,450	20 to 24
5	63	9	45	1,590	4-1/2	6-1/4	8		42 to 48	130	780	1,040	1,300		26	3,600	4,000	20 to 24
6	66	9	48	1,809	5-1/2	7-1/4	9	10-3/4	45 to 51	145	870	1,170	1,450	1,740	29	4,100	4,500	24 to 28
7	72	9	54	2,290	7	9-1/4	11-1/2	13-3/4	45 to 51	185	1,100	1,480	1,850	2,220	37	5,200	5,750	24 to 32
8	78	9	60	2,827	9	11-1/4	14	17	45 to 51	225	1,350	1,800	2,250	2,700	45	6,400	7,100	24 to 32
9	84	9	66	3,421	10-1/2	13-3/4	17	20-1/2	45 to 51	275	1,650	2,200	2,750	3,300	55	7,700	8,650	24 to 32
9-1/2	90	9	72	4,071	12-1/4	16-1/2	20-1/4	24-1/2	47 to 51	325	1,950	2,600	3,250	3,900	65	9,250	10,200	28 to 36
10	96		78	4,778	15	15	21-3/4	26-3/4	47 to 51	385	2,300	3,080	3,850	4,600	77	10,700	11,900	28 to 38
11	102	12	78	4,778	15	15	21-1/4	28-3/4	47 to 53	385	2,300	3,080	3,850	4,600	77	10,700	11,900	28 to 40
12	108	12	84	5,542	17	22-1/4	27-3/4	33-1/4	47 to 53	445	2,670	3,560	4,450	5,400	89	12,500	13,900	32 to [illegible]

[a] For long heats, use heavier linings.

[b] Height of bed coke varies as square root of blast pressure. Recommend blowers with 20-oz discharge pressure when air weight control is used.

[c] Additional pressure capacity may be required when auxiliary equipment is added to the blast system, or when piping is long or complicated.

Table 7.9.2. DUST AND FUME EMISSIONS FROM GRAY IRON CUPOLAS (SOURCE: LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT, Reference 1)

Test No.	1	2	3	4	5	6	7
Cupola data							
Inside diameter, in.	60	37	63	56	42	60	48
Tuyere air, scfm	-	1,950	7,500	-	-	-	-
Iron-coke ratio	7/1	6.66/1	10.1/1	6.5/1	9.2/1	9.6/1	7.4/1
Process wt, lb/hr	8,200	8,380	39,100	24,650	14,000	36,900	16,800
Stack gas data							
Volume, scfm	8,300	5,520	[illegible]0,500	17,700	20,300	21,000	8,430
Temperature, °F	1,085	1,400	213	210	430	222	482
CO_2, %	-	12.3	2.8	4.7	5.2	-	-
O_2, %	-	-	-	12.7	11.8	-	-
CO, %	-	-	-	0	0.1	-	-
N_2, %	-	-	-	67.5	67.3	-	-
Dust and fume data							
Type of control equipment	None	None	None	Baghouse	Elec precip afterburner	Baghouse	Elec Precip
Concentration, gr/scf							
Inlet	-	-	-	1.33	2.973	0.392	1.522
Outlet	0.913	1.[illegible]	0.413	0.051	0.0359	0.0456	0.186
Dust emission, lb/hr							
Inlet	-	[illegible]	-	197	184.7	70.6	110
Outlet	65	[illegible]	108	7.7	6.24	8.2	13.2
Control efficiency, %	-	-	-	96	96.6	88.4	87.7
Particle size, wt %							
0 to 5 μ	18.1	17.2	23.6	25.8	-	-	-
5 to 10 μ	6.8	8.5	4.5	6.3	-	-	-
10 to 20 μ	12.8	10.1	4.8	2.2	-	-	-
20 to 44 μ	32.9	17.3	9.5	10.0[a]	-	-	-
> 44 μ	29.3	46.9	57.9	55.7[b]	-	-	-
Specific gravity	3.34	2.78					

[a] From 20 to 50 μ.

[b] Greater than 50 μ.

The requirements for controlling the emission of air contaminants from cupolas vary with different agencies. The criteria for control may be emission opacity or dust and fume discharge (process weight, see Chapter 3). Water type collectors can be used if it is necessary to remove large particles of dust but effective dust and fume collection requires baghouses or electrical precipitators including CO afterburners and gas coolers. Table 7.9.3 describes pilot test results of various air pollution control devices used on cupolas.

2. Inspection Points

Cupolas operating without air pollution control systems emit dense grey brown smoke and fumes when the blast air is in use. Furnaces with air pollution control systems should be inspected during the start up, melting and pouring phases of operation. An observation should also be made of the bottom dropping operation to make certain that time and opacity limits are not exceeded.

In systems using a baghouse it is essential that an adequately designed afterburner be in operation during melting to reduce the CO content of the gas in order to minimize the explosion hazard and to burn oil mists and vapors. Any system designed to handle cupola gases must be sized to provide good indraft at the charging opening. Puffing can occur frequently and the use of charging port doors plus a high indraft will minimize losses from this area. Observation of the effluent from the control equipment can provide qualitative readings of the efficiency of collection. Stack tests are required to determine if the grain loading of the exhaust gases meets compliance standards.

Table 7.9.3. SOME COLLECTION EFFICIENCIES OF EXPERIMENTAL SMALL-SCALE CONTROL DEVICES TESTED ON GRAY IRON CUPOLAS[a] (SOURCE: LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT, Reference 1)

Equipment tested	Inlet gas volume, acfm	Outlet gas volume, acfm	Inlet dust load, gr/acf	Outlet dust load, gr/acf	Collection efficiency, %	Remarks
Controls for cupolas[b]						
High-efficiency cyclone	330	384	1.225	0.826	22.5	
Dynamic water scrubber	1,410	1,760	1.06	0.522	38.2	Water added before control unit for cooling totalled 6 gpm
Venturi-type scrubber	375	432	1.17	0.291	71.3	Two gpm-water introduced for cooling gas stream; 1.5 gpm added at venturi throat; cyclonic scrubber operated dry
Dynamic--impingement wet scrubber	605	905	0.95	0.141	75.6	Water rate in excess of 10 gpm
Baghouse--one silicone-treated glass wool bag, 10 in. dia x 10 ft length	92.7	92.7	1.32	0.046	96.5	Average temp, 172°F; average filtering velocity, 3.22 gpm
Evaporative cooler and reduced pipe electrical precipitator	1,160	1,330	1.263	0.0289	97.7	Water rate to cooler, 22 gpm; to precipitator, 2 gpm
Other basic equipment						
Natural gas-fired reverberatory furnace	--	6,160	--	0.00288	96.2[c]	Melting rate, 546 lb/hr; gas consumption rate, 4,200 cfh; melting clean scrap and pig iron

[a] In all cases, equipment was installed and operated according to the manufacturer's recommendations.

[b] The six control devices were tested on the same cupola.

[c] This is not an actual collection efficiency, but a percent reduction when compared with average cupola emissions.

C. NON-FERROUS FOUNDRIES

Foundries form a part of nearly all industrial complexes and are found in all parts of the country. These consist of small single crucible furnace shops or large production die casting shops employing many banks of melting furnaces. The number and types of core making equipment, mechanical sand mullers, sand handling, grinding, buffing and plating equipment will depend upon the size of the operation and the end-use of the product. For example, foundries producing plumbing fixtures may have chrome plating facilities.

Since the range of practices, equipment and alloys is extensive non-ferrous foundries will be treated as an entity describing operations and equipment, alloys melted, potential emissions, air pollution control systems and inspection practices. Non-ferrous foundries can be classified according to the metals melted: copper-base alloys (brass and bronze), aluminum, or zinc.

1. Process Description--Copper-Base Alloys

Brass and bronze are the common names for a group of copper base alloys composed of 60 to 90 percent copper, zinc, lead, tin and fractional percentages of other metals. Brasses usually contain 60-65 percent copper; bronzes usually contain 85-90 percent. Particulate emissions from melting operations originate from condensed metallic fume; particulates from fuel-fired furnaces originate from the products of combustion (see Fuel-Burning Equipment, Chapter 6, Section II).

Table 7.9.4 illustrates uncontrolled emission rates from a variety of furnaces melting copper base alloys with zinc content ranging from 5 to 38 percent. Since high copper alloys (80 to 90 percent copper) have a fairly high boiling point the fuming rate will be low; however, when the zinc content increases, as in alloys with 20 to 40 percent

Table 7.9.4. DUST AND FUME DISCHARGE FROM BRASS FURNACES (SOURCE: LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT, Reference 1)

Type of furnace	Composition of alloy, %					Type of control	Fuel	Pouring temp, °F	Process wt, lb/hr	Fume emission lb/hr
	Cu	Zn	Pb	Sn	Other					
Rotary	85	5	5	5	-	None	Oil	No data	1,104	22.5
Rotary	76	14.7	4.7	3.4	0.67 Fe	None	Oil	No data	3,607	25
Rotary	85	5	5	5	-	Slag cover	Oil	No data	1,165	2.73
Elec ind	60	38	2	-	-	None	Elect	No data	1,530	3.47
Elec ind	71	28	-	1	-	None	Elect	No data	1,600	0.77
Elec ind	71	28	-	1	-	None	Elect	No data	1,500	0.54
Cyl reverb	87	4	0	8.4	0.6	None	Oil	No data	273	2.42
Cyl reverb	77	-	18	5	-	None	Oil	2,100	1,267	26.1
Cyl reverb	80	-	13	7	-	Slag cover	Oil	2,100	1,500	22.2
Cyl reverb	80	2	10	8	-	None	Oil	1,900 to 2,100	1,250	10.9
Crucible	65	35	-	-	-	None	Gas	2,100	470	8.67
Crucible	60	37	1.5	0.5	1	None	Gas	1,800	108	0.05
Crucible	77	12	6	3	2	Slag cover	Gas	No data	500	0.822

zinc, the boiling point will drop considerably and increased fuming will result. Pure zinc boils at 1663°F with the usual pouring temperature of high zinc alloys between 1900°F and 2100°F which would allow some zinc to form zinc oxide as it flashes from the furnace and is released as dense white emissions. Emissions from the melting of high lead alloys will contain as much as 56 percent lead oxide.(2)

Furnaces used in brass foundries are either direct fired types which include pit and tilting crucible furnaces and cylindrical reverberatory furnaces, or indirectly heated electric induction furnaces. Of the two types the indirectly heated furnaces will produce smaller amounts of emissions per pound of metal melted than direct fired furnaces.

In pit type furnaces, the crucible is made of silicon carbide or other refractory material, and is indirectly heated in a ceramic-lined pit by either natural gas or oil. The cycle consists of melting the charge and flux (see Table 7.9.5), removing the crucible from the pit and pouring the metal into the molds. As in most brass melting operations the emissions will be mostly zinc oxide or lead oxide. Where the alloy melted has a high copper content, 85 percent to 90 percent, emissions can be curtailed and brought within the limits of most opacity and process weight regulations by the use of a proper slag cover, usually molten glass, which is punctured only during pouring. A slag thickness of 1/4" to 3/8" is recommended. Considerable fuming occurs when the molten metal is poured. When yellow brass is melted (alloys with less than 80 percent copper) an air pollution control system should be required to capture the fumes emitted during melting and pouring.

Tilt type crucible furnaces do not vary significantly in operation from pit type furnaces. The tilting furnace is usually larger in capacity, is located above floor level and is fired with either gas or oil (see Figure 7.9.2).

Table 7.9.5. RELATIVE VOLATILITIES AND MELTING TEMPERATURES FOR NON-FERROUS METALS (SOURCE: LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT, Reference 3)

METALS	APPROXIMATE MELTING TEMPS.	RELATIVE VOLATILITY	FLUXES USED
Zinc Alloys	650°— 700°F	1	Ammonium chloride
Lead Alloys	500°— 650°F	2	Sodium Nitrate Sal amoniac Lump sulphur
Magnesium Alloys	800°— 900°F	3	Dow #1 and #2 Flowers of sulphur
Aluminum Alloys	1250°—1280°F	4	Chlorine gas Aluminum chloride Zinc chloride Aluminum fluoride
Copper Alloys (Manganese bronze)	Around 1800°F 1650°—2000°F	5	Silica sand blown with air Soda ash Borax

In brass and bronze melting operations (copper alloys), zinc is the first base metal to fume because of its low melting temperatures in relation to copper. Copper alloys containing more than 5% zinc are likely to fume without proper controls. In particular, the following metals must be carefully controlled: Yellow Brass, 20% or more zinc; Manganese Bronze, up to 45% zinc; Brazing Spelter, 40% zinc; Plumbing Metals, 12% zinc. Copper alloys of less than 5% zinc content, such as Red Brass, are not likely to fume and may not require controls.

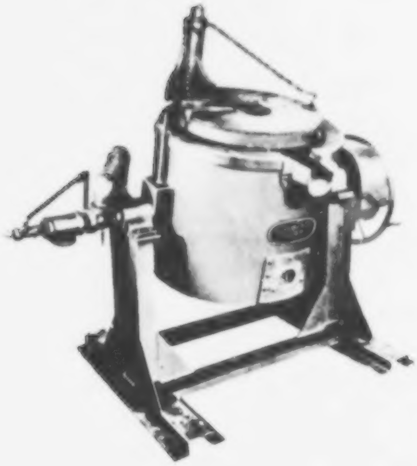

Figure 7.9.2. TILTING CRUCIBLE FURNACE, LINDBERG ENGINEERING CO., DOWNEY, CALIF. (SOURCE: LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT, Reference 1)

Induction furnaces offer by far the most rapid method of melting metal in common use by foundries. Temperature control can be carefully maintained, which is a prime factor in zinc oxide and lead oxide emissions resulting from the melting of copper base allovs. In the operation of induction furnaces, granulated charcoal has been found to be superior as a flux to glass and borax which are destructive to the furnace walls. Charging fluxes into a hot furnace and metal pouring remain the critical periods in the overall operating cycle in the emissions of dusts and fumes.

Cylindrical rotary furnaces present the greatest potential air pollution problem of the group of furnaces commonly used in brass foundries. These are reverberatory furnaces in which the flame from the burners impinge on the surface of the metal. There are several variations of this type of furnace but the operating procedures are virtually the same (see Figure 7.9.3). The furnace rotates on its horizontal axis and tilts for pouring and charging (Figure 7.9.4). Due to the shape of the furnace and the large volume of gas exhausted from the products of combustion, the velocity of the gases leaving the furnace is very high. Therefore, tight hooding and high inlet velocities at the hoods are required to assure acceptable fume capture.

Since the products of combustion come into contact with the metal in a cylindrical reverberatory furnace it is decirable to have a slightly oxidizing atmosphere to avoid smoke from combustion when oil is fired and to prevent gas entrapment in the metal resulting from unburned fuel and water vapor. While this is an operational problem, improper combustion could cause smoke and fume generation which can be avoided by good operating practice.

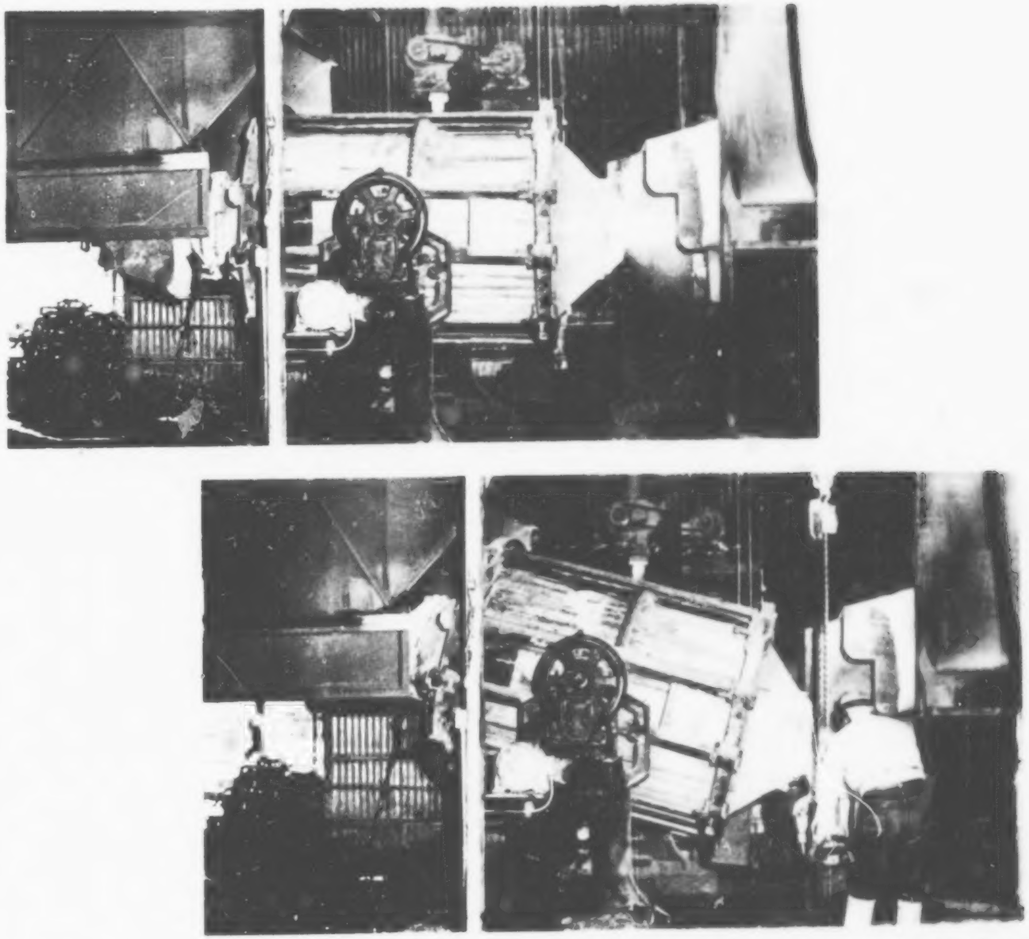

Figure 7.9.3. ROTARY-TILTING-TYPE REVERBERATORY FURNACE VENTING TO CANOPY HOOD AND STACK VENT. (Top) Furnace during meltdown, (Bottom) furnace during pour, VALLEY BRASS, INC. EL MONTE, CALIF. (SOURCE: LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT, Reference 1)

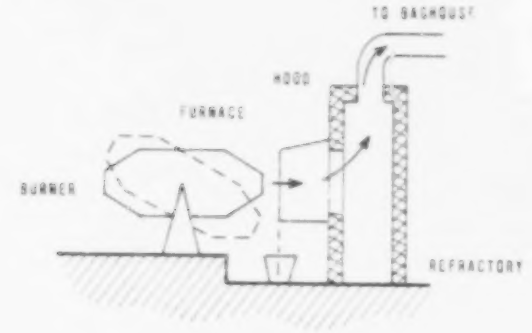
TO BAGHOUSE
HOOD
FURNACE
BURNER
REFRACTORY

Figure 7.9.4. ROTARY-TILTING-TYPE BRASS-MELTING FURNACE (SOURCE: LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT, Reference 1)

The operation of these furnaces varies in melting time, method of heating, and in the physical shape of the equipment. There is strong similarity, however, in the air pollution potential from the common phases of the operating cycle: charging, working and pouring. Observations of these critical periods is mandatory in determining compliance with ordinances governing non-ferrous foundry operations.

2. Inspection Points--Copper-Base Alloys

Foundries are usually a part of an integrated manufacturing facility which includes machine shops, plating facilities, packaging and shipping departments. It is reasonable to assume, therefore, that metal charged to the furnace for melting will be made up of scrap parts, gates and risers, turnings and borings, as well as ingot metal.

a. CHARGING--the condition of the metal charged should be closely inspected to determine if there is grease or oil present. Usually, in foundry practice, the charge will consist of rejected parts, gates and risers, and ingot; however occasionally some other scrap of known analysis can be used as an economy measure. Dirty and oily material can add combustion-related contaminants to the effluent such as smoke and particulates. Charging metals into the furnace after the heel has formed, will break the slag cover and allow significant quantities of fume to escape. The inspector should time this operation for opacity violations in uncontrolled operations and check the hood pickup efficiency in controlled operations. Maintaining the integrity of the slag cover is essential to good operating conditions in melting brass and bronze. Any action which breaks the cover will allow the escape of dense emissions of metallic oxides.

b. MELTING--prior to charging the metal the flux material (crushed glass, borax and, in induction furnaces, granulated charcoal) is placed in the furnace so that as melting occurs the slag will form over the metal to inhibit contact or mixing with air. The slag must be skimmed to remove trapped materials whenever additional flux or metal is to be added to the furnace. This results in heavy emissions. Properly designed air pollution control systems, with high indraft velocities at the hoods are required to capture these emissions. Time and opacity, and process weight regulations are frequently violated in this phase of the operation.

c. POURING--temperatures of the metal during pouring are important for the type of casting produced and are therefore carefully controlled. The pouring temperature is also very important from an air pollution control standpoint since the higher the temperature of the alloy the more volatilization will occur. For a given percentage of zinc an increase of 100°F increases the rate of loss of zinc about three times.(1)

As has been mentioned, breaking the slag cover for whatever reason causes heavy fuming to occur. When pouring from a crucible or ladle it is necessary to punch two holes in the slag cover; one to allow air in and the other to pour. All transfer operations will cause fuming by exposing the molten metal to air and allowing oxides to form. In order to comply with process weight and opacity regulations some foundries that melt yellow brass have found it necessary to mechanize the pouring operation so that the molds pass under a hood and the ladle is stationary. Various systems are in use, some employing hoods with flexible ducting to capture the fume produced during pouring.

The Air Pollution Engineering Manual sets forth the factors which cause extensive emissions of zinc fumes, and which form the basis for understanding the operational causes of these emissions.

1. Alloy composition. The rate of loss of zinc is approximately proportional to the zinc percentage in the alloy.

2. Pouring temperature. For a given percentage of zinc, an increase of 100°F increases the rate of loss of zinc about three times.

3. Type of furnace. Direct-fired furnaces produce larger fume concentrations than the crucible type does, other conditions being constant. The Los Angeles Nonferrous Foundrymen's Committee, stated, "It is improbable that any open-flame furnace melting alloys containing zinc and lead can be operated without creating excessive emissions. It is conceded that anyone choosing to operate that type of furnace will be required to install control equipment "

4. Poor foundry practice. Excessive emissions result from improper combustion, overheating of the charge, addition of zinc at maximum furnace temperature, flame impingement upon the metal chargec, heating the metal charged, heating the metal too fast, and insufficient flux cover. Excessive superheating of the molten metal is to be avoided for metallurgical and economic as well as pollution control reasons. From an air pollution viewpoint, the early addition of zinc is preferable to gross additions at maximum furnace temperatures."

The most effective air pollution control equipment for brass foundry melting and pouring operations are baghouses and electrical precipitators. Of equal importance is the collection system which includes hoods, ductwork, gas temperature reduction mechanisms and fans.

The design of fume pickup systems presents difficult air pollution control problems especially when high temperature gas is to be captured from a source where access by workmen is required and where the source may not be stationary as in operations where metal is poured from movable ladles. Generally if these systems have been installed, prior approval from the air pollution control agency is needed to assure that the design characteristics have been thoroughly evaluated and necessary tests have been conducted. The inspector must check these systems to determine that the operating effectiveness has not deteriorated due to poor maintenance or improper use; or, if prior approval was not obtained, to determine if the system has been properly designed for the job.

3. Process Description--Aluminum Melting

Aluminum foundries that melt ingots, rejects, gates and risers in crucible or induction furnaces are not major sources of air pollution if fluxes are not used for cleaning, alloying, degassing or removal of magnesium (demagging). The furnaces used in aluminum foundries are of the pit crucible, tilt or induction type. Since indirect heating is used there is no problem from mixing the products of combustion with the molten aluminum.

A flux cover can be used to prevent oxidation on the surface of the metal. The flux usually consists of mixtures of sodium chloride, calcium chloride, calcium fluoride and borax.

Aluminum castings are made in either sand molds or in die casting machines. There is a certain amount of off-gassing from sand casting which is related to the type of cores used and the moisture content of the foundry sand. (See Coremaking, this Section.) Die casting should not be a problem if a mold release compound containing no oil is used.

The major air pollution control problems from melting aluminum arises from secondary smelting and refining which is discussed in Section XIII of this chapter.

A typical melting cycle consists of charging the metal into the furnace after a heel has formed, fluxing and pouring. The average fluxing temperature is 1250°F to 1280°F. In small crucibles the metal is poured directly from the crucible into the mold. In the larger tilt type furnaces the molten aluminum is poured into ladles and transferred to the sand casting area of the plant for pouring into sand molds or into smaller hand held ladles for pouring into die casting machines.

4. Process Description--Zinc Melting

Foundries melting zinc alloys in pit crucibles, tilt crucible, pot furnaces, or induction furnaces usually do not use fluxes. The metal is melted and heated to the desired pouring temperatures which may range from 800°F to 1100°F. At these temperatures little vaporization and virtually no visible emissions occur. Zinc vaporizes at 1665°F. The necessity to heat zinc to temperatures approaching this figure in non-ferrous foundries does not occur.

Many zinc foundries use die casting machines which require a mold release compound. If a non-oily compound is used there should be no smoking or oil mist generated from the molds after pouring.

In the zinc melting operating cycle it is not necessary to form a heel before charging except in induction furnaces. Usually ingot and rejects are charged before scrap and thin-walled sections to prevent burning. If the metal charged is dirty, dross will form on the surface of the molten metal which must occasionally be skimmed. Flux may be added to help float any submerged dross to the surface. Dross is the common name applied to a mixture of oxide and impurities which form when the white metals are melted.

If a zinc melting furnace is creating visible emissions the most likely causes are: the vaporization of oil, grease or paint from the metal charged; unusually high temperatures which cause the zinc to flash to zinc oxide; or the use of a boiling flux which is intended for melts containing less ingot in relation to scrap metal.

These operations do not require air pollution control systems and can meet most opacity and process weight regulations if they are controlled under the conditions described above.

5. Inspection Points--Aluminum and Zinc

In both aluminum and zinc melting operations it is necessary for the inspector to observe a complete cycle from charge to pour to become completely familiar with the operating procedures of the firm. The critical phases of operation common to both are metal charging to determine if oily material is used, fluxing and dross removal. The pouring of zinc into ladles or molds can also be critical if the temperature greatly exceeds 1100°F.

6. Process Description--Core Making

Core making is an integral part of foundry operations and is a potential source of air pollution under certain operating conditions. It is generally difficult to record opacity violations from core ovens. The equipment can be a source of public nuisance, however.

Cores are used to allow molten metal to flow around a given space to form the desired cavity in a casting. The core therefore must be non-reactive, firm and easily removed after the metal has solidified. Sand is mixed with binders which when heated will provide the strength that the core requires to keep it firm while the mold is being prepared and to resist skrinking or warping when the metal is poured into the mold. The binders when heated either change chemically, physically or both and can emit volatiles such as aldehydes and solvent vapors.

Typical binder mixtures contain linseed oil, gum resin, cereal binder, kerosene, and water which are proportioned according to the quantity of sand used. As heat is applied in the core oven the light oil fractions distill off first. As the temperature continues to increase the heavier fractions are vaporized and polymerization of the linseed oil occurs. As the temperature in the oven continues to rise towards its maximum of 400°F the rosin melts, coating the sand grains with a thin film. The remaining curing time is necessary to reach maximum strength of the core.

A variety of ovens are used to bake cores, both gas and oil fired, batch and continuous. Figures 7.9.5 through 7.9.8 illustrate the types and size of ovens that can be found in foundries. The operating cycle is dependent upon the type of binder used and ranges from 1 to 4 hours.

Emissions from core baking are organic acids, aldehydes and smoke. Examples of quantitative emissions are shown in Table 7.9.6.

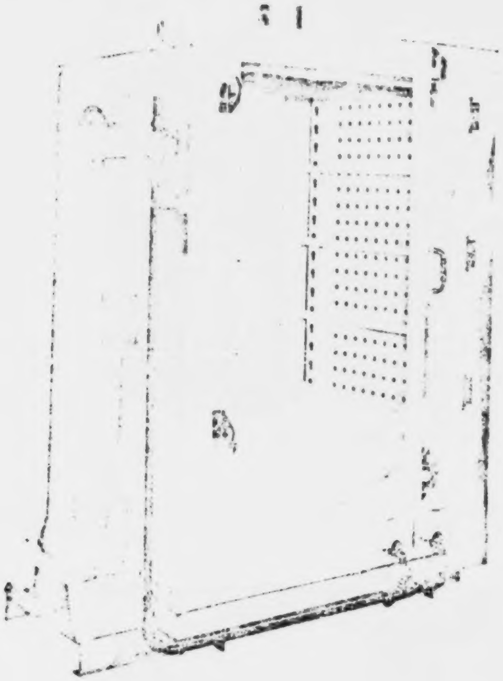

Figure 7.9.5. SHELF OVEN, THE FOUNDRY EQUIPMENT CO., CLEVELAND, OHIO (SOURCE: LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT, Reference 1)

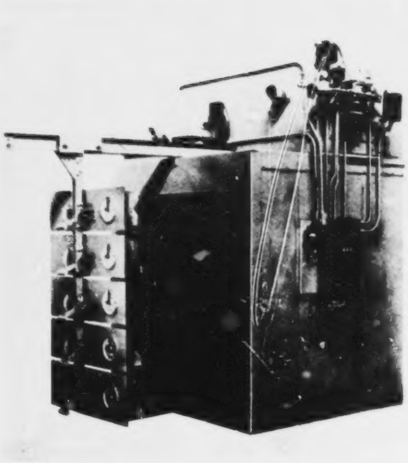

Figure 7.9.6. DRAWER OVEN, DESPATCH OVEN CO., MINNEAPOLIS, MINN. (SOURCE: LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT, Reference 1)

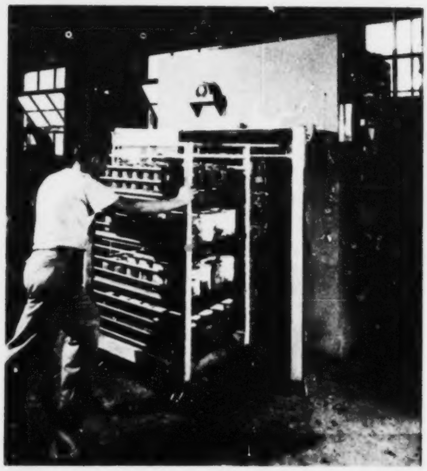

Figure 7.9.7. RACK OVEN, DESPATCH OVEN CO., MINNEAPOLIS, MINN. (SOURCE: LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT, Reference 1)

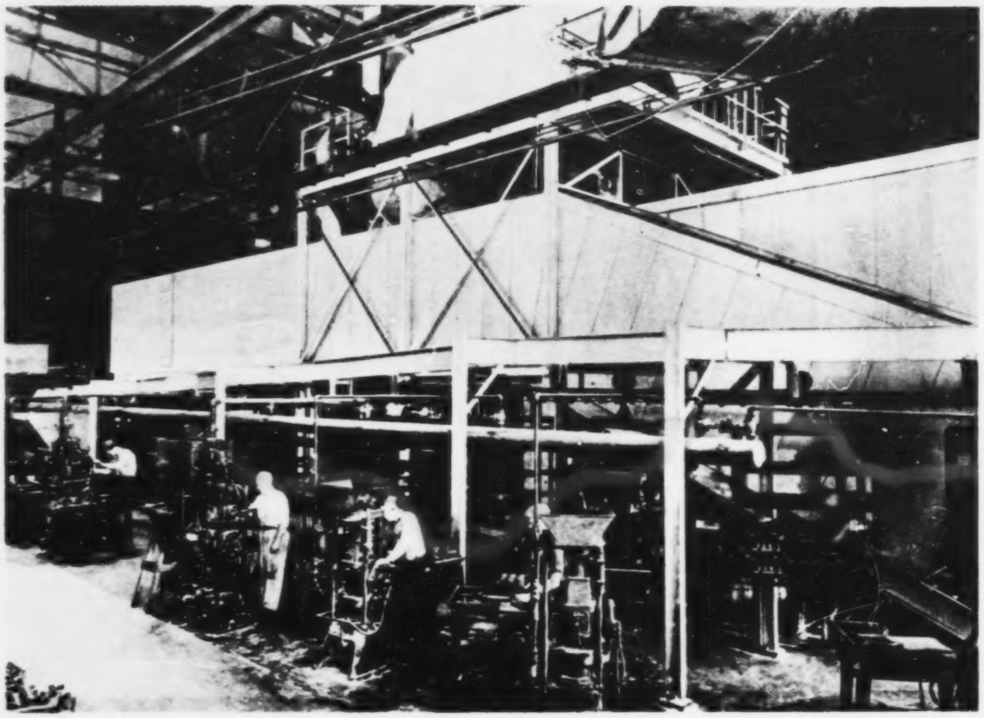

Figure 7.9.8. HORIZONTAL, CONTINUOUS OVEN, THE FOUNDRY EQUIPMENT CO., CLEVELAND, OHIO (SOURCE: LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT, Reference 1)

Table 7.9.6. AIR CONTAMINANT EMISSIONS FROM CORE OVENS (SOURCE: LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT, Reference 1)

Test No.	1	2		3	
Oven data					
Size	6 ft 2 in. W x 7 ft 11 in. H x 19 ft L	3 ft 10 in. W x 5 ft 3 in H x 18 ft L		4 ft 2 in. W x 6 ft 8 in. H x 5 ft 9 in. L	
Type	Direct gas-fired	Direct gas-fired		Indirect electric	
Operating temp, °F	380	400		400	
Core binders	1 to 1/2% phenolic resin	3% linseed oil		1% linseed oil	
Weight of cores baked, lb	700	1,600		600	
Baking time, hr	11	2-1/2 to 3		6	
Afterburner data					
Size		10 in. dia x 7 ft 6 in. H		3 ft dia x 4 ft H	
Type	None	Direct flame		Direct flame	
Burner capacity, Btu/hr		200,000		600,000	
Air contaminants from:	Oven	Oven	Afterburner	Oven	Afterburner
Effluent gas volume, scfm	100	140	260	250	440
Effluent gas temperature, °F	380	400	1,400	400	1,780
Particulate matter, lb/hr	0.13	0.2	0.013	0.27	0.02
Organic acids, lb/hr	0.068	0.008	0.000	0.44	0.087
Aldehydes, ppm	52	10	10	377	4
Hydrocarbons, ppm	124	-	< 10	158	< 19
Opacity, %	0	-	0	-	0
Odor	Slight	-	Slight	-	None

Ovens which operate at 400°F or less on a batch basis can usually meet most air pollution control regulations and should not cause a public nuisance. Excessive emissions are likely to occur when large quantities of cores are baked or continuous operations are employed and curing temperatures exceed 450°F to 475°F.

The most effective air pollution control system to reduce these emissions is an afterburner or vapor incinerator. A combustion zone temperature of 1200°F, good mixing and at least 0.3 second retention time are minimums for good control.

7. Inspection Points--Core Making

The inspector should observe at least the last hour of the core baking operation to determine if odors can be detected from the oven vent or an opacity violation occurs. If the agency has specific rules governing the emission of organic gases and vapor it may be necessary to request a stack test to make a quantitative and qualitative determination of the emissions. In either case, he should learn the trade name or specification of the binder used, the maximum oven temperature, cure time and time of day the equipment is operated.

8. Process Description--Sand Handling

Foundry sand handling systems are usually mechanized in production shops but are fundamentally the same regardless of the size of the foundry. Molds are shaken to loosen the sand from the casting in the shakeout pit. The sand, spent cores and small particles of metal fall onto a screen which passes the proper particle size sand and segregates the oversized material. A minimum reconditioning system includes a crusher, conveyor and muller in which the sand is mixed with clay and water to bring it to the proper condition to be reused in molds. The sand at shakeout is hot and must be cooled prior to reconditioning. This can be accomplished by ambient air or in large volume operations where there is a high metal-to-sand ratio in the mold, and by mechanical air blowing equipment. Figure 7.9.9 shows a complete sand handling and dust control system.

In addition to dust there are some smoke and organic vapor emissions from this phase of foundry operations. After the pour into the mold is complete some of the core binder material will break down creating smoke and vapors. This will continue to some degree during shakeout. Ventilation systems designed to capture fines and smoke are usually a part of the integrated system. If a baghouse is used as control equipment and is properly sized and maintained, emissions to the atmosphere can be held within most emission limitations. Scrubbers will reduce the dust emissions but have not proven effective for eliminating smoke.

9. Inspection Points--Sand Handling

A survey should be made of the sand handling and conditioning system to determine if excessive dust and smoke are emitted. If there is a dust collection system the inspector must check all tranfer points, the boot and discharge of the bucket elevator, and vibrating screens. Hoods should have adequate indraft velocity to capture the dust generated by the material handling equipment and air blowing, if used. In foundries not using dust control systems, a qualitative estimate of dust losses should be made to determine if a dust control system is required. Smoking molds and sand could be a cause for complaints and may violate opacity regulations.

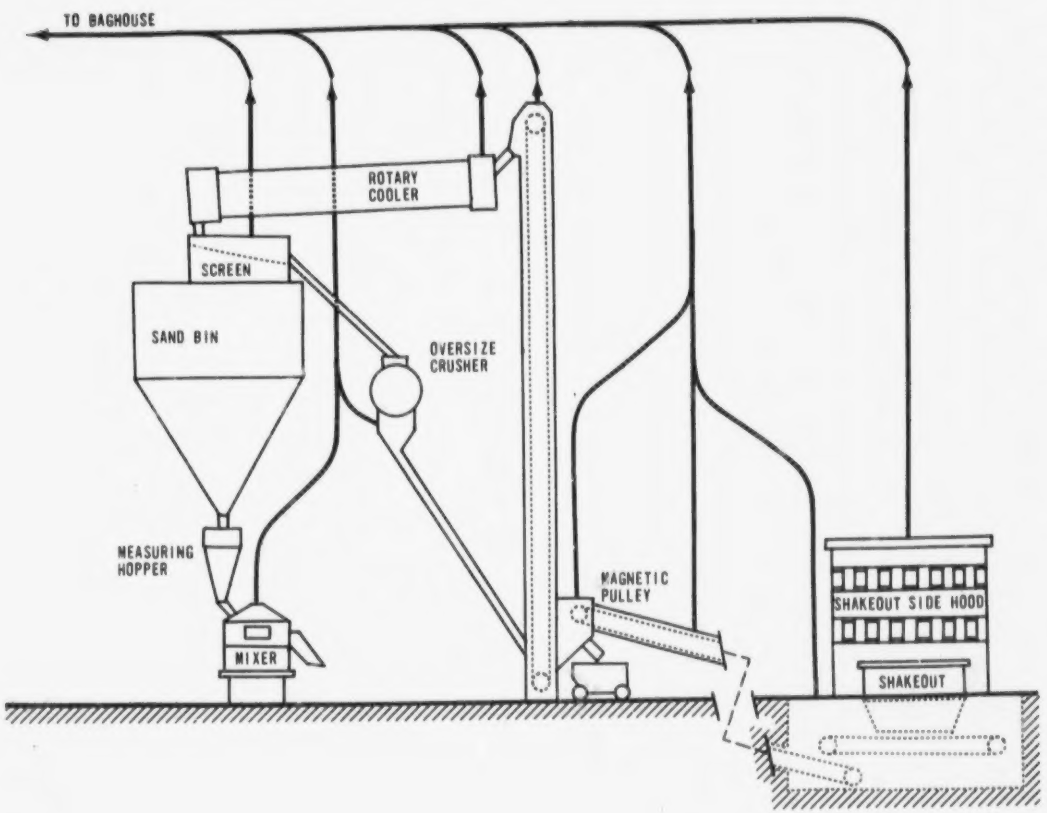
TO BAGHOUSE
ROTARY COOLER
SCREEN
SAND BIN
OVERSIZE CRUSHER
MEASURING HOPPER
MIXER
MAGNETIC PULLEY
SHAKEOUT SIDE HOOD
SHAKEOUT

Figure 7.9.9. TYPICAL FOUNDRY SAND-HANDLING SYSTEM (SOURCE: LOS ANGELES COUNTY AIR POLLUTION CONTROL DISTRICT, Reference 1)

10. Environmental Observations

Emissions of aldehydes and other organic material from foundries are sometimes a source of nuisance complaints and can be traced to the foundry core making operation or to the vaporization of the binder materials after metal has been poured into the mold. These organic materials can cause eye, nose, and throat irritation. Visible emissions from metal melting can be easily observed from outside of the plant and related to a particular phase of the operation after the inspector has observed the complete melting cycle.

Dust and fines from sand handling, storage piles and unpaved areas in a foundry are also prime causes of complaints. A survey of nearby residents or business establishments can usually result in isolating the offending company.

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X. CEMENT PLANTS

A. DESCRIPTION OF SOURCE

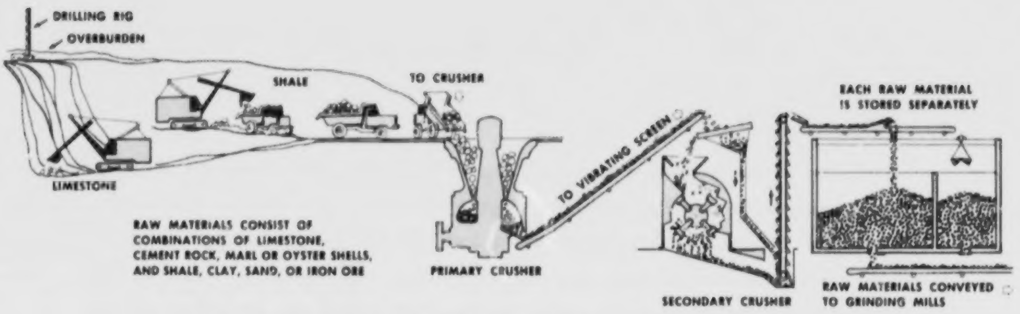
Portland cement takes its name from a fine building stone it resembles when made into concrete, which is quarried on the isle of Portland, England. Portland cement is manufactured in 180 plants in the United States. The raw materials--limestone, cement rock, clay and iron ore--are either blended dry or mixed with water to form a slurry and then burned into cement clinkers. These two processes account for all of the 500,000,000 barrels of Portland cement produced in the United States.(1)

Due to the increasing use of Portland cement, the anticipated annual growth rate of this industry is 5% per year with a trend toward larger plants

Cement plants are located throughout the United States with the greatest production occuring in eastern Pennsylvania; Maryland; Alabama; Missouri; Central Texas; California and the Pacific Northwest.(2)

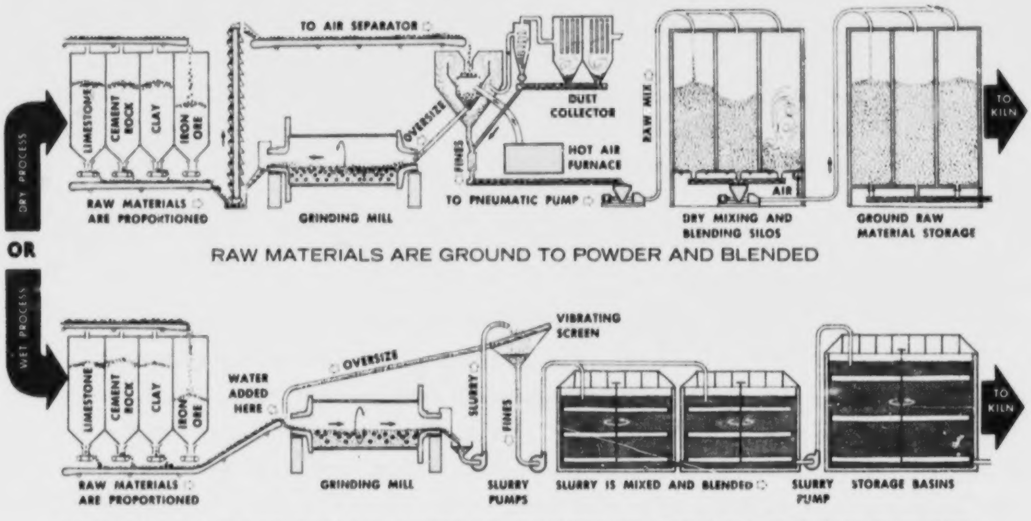
B. PROCESS DESCRIPTION

The process begins with quarrying of the raw materials, transporting by truck, rail, or barge to primary crushers for initial size reduction, and transporting by conveyor to secondary crushers for further size reduction and storage (Figure 7.10.1). In the wet process the raw materials are proportioned according to the desired cement specification, and mechanically conveyed to a grinding mill where water is added. The resulting slurry is pumped to a vibrating screen which passes the wet mixture containing the specified size fines to the blending tanks and diverts the oversized material back to the grinder. The slurry is mixed and blended and is then pumped into a final storage vessel before introduction into the kiln.


DRILLING RIG
OVERBURDEN
SHALE
TO CRUSHER
LIMESTONE
TO VIBRATING SCREEN
EACH RAW MATERIAL IS STORED SEPARATELY
RAW MATERIALS CONSIST OF COMBINATIONS OF LIMESTONE, CEMENT ROCK, MARL OR OYSTER SHELLS, AND SHALE, CLAY, SAND, OR IRON ORE
PRIMARY CRUSHER
SECONDARY CRUSHER
RAW MATERIALS CONVEYED TO GRINDING MILLS

STONE IS FIRST REDUCED TO 5-IN. SIZE, THEN ¾-IN., AND STORED

1


DRY PROCESS
OR
WET PROCESS
TO AIR SEPARATOR
LIMESTONE
CEMENT ROCK
CLAY
IRON ORE
OVERSIZE
FINES
DUST COLLECTOR
HOT AIR FURNACE
RAW MIX
AIR
TO KILN
RAW MATERIALS ARE PROPORTIONED
GRINDING MILL
TO PNEUMATIC PUMP
DRY MIXING AND BLENDING SILOS
GROUND RAW MATERIAL STORAGE
VIBRATING SCREEN
OVERSIZE
WATER ADDED HERE
SLURRY
FINES
TO KILN
RAW MATERIALS ARE PROPORTIONED
GRINDING MILL
SLURRY PUMPS
SLURRY IS MIXED AND BLENDED
SLURRY PUMP
STORAGE BASINS

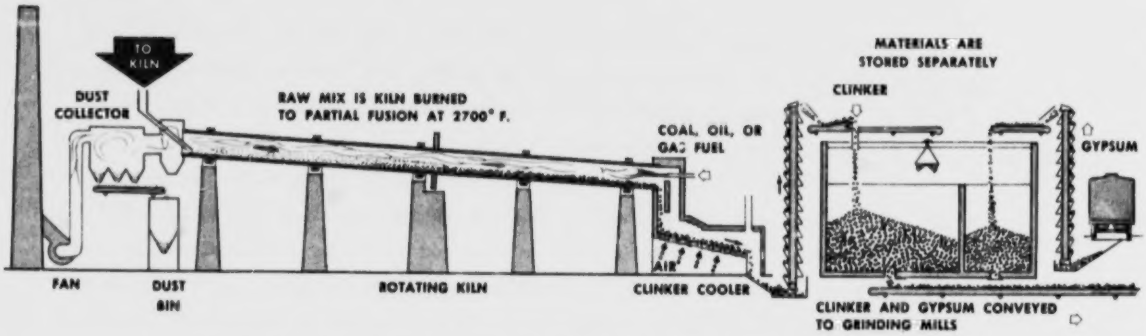
RAW MATERIALS ARE GROUND TO POWDER AND BLENDED

RAW MATERIALS ARE GROUND, MIXED WITH WATER TO FORM SLURRY, AND BLENDED

2

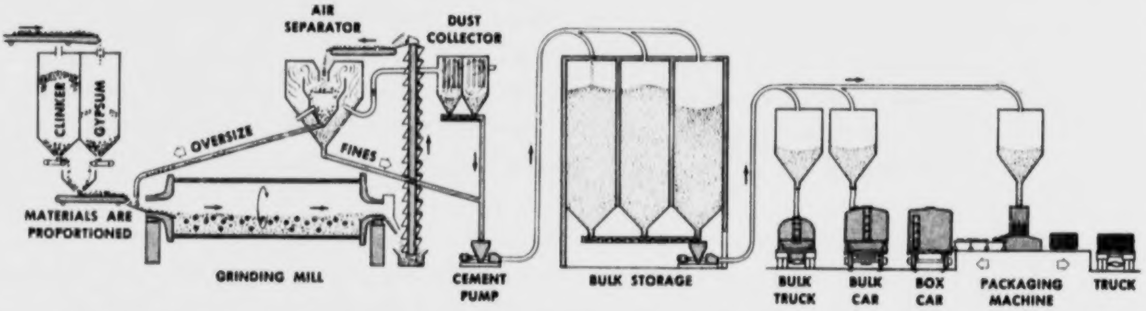
Figure 7.10.1. PROCESS STEPS--PORTLAND CEMENT PRODUCTION

(SOURCE: PORTLAND CEMENT ASSOCIATION, Reference 3)


TO KILN
DUST COLLECTOR
RAW MIX IS KILN BURNED TO PARTIAL FUSION AT 2700° F.
COAL, OIL, OR GAS FUEL
MATERIALS ARE STORED SEPARATELY
CLINKER
GYPSUM
AIR
FAN
DUST BIN
ROTATING KILN
CLINKER COOLER
CLINKER AND GYPSUM CONVEYED TO GRINDING MILLS

BURNING CHANGES RAW MIX CHEMICALLY INTO CEMENT CLINKER

3


AIR SEPARATOR
DUST COLLECTOR
CLINKER
GYPSUM
OVERSIZE
FINES
MATERIALS ARE PROPORTIONED
GRINDING MILL
CEMENT PUMP
BULK STORAGE
BULK TRUCK
BULK CAR
BOX CAR
PACKAGING MACHINE
TRUCK

CLINKER WITH GYPSUM ADDED IS GROUND INTO PORTLAND CEMENT AND SHIPPED

4

Figure 7.10.1. PROCESS STEPS--PORTLAND CEMENT PRODUCTION (continued)

(SOURCE: PORTLAND CEMENT ASSOCIATION, Reference 3)

In the dry process the proportioned raw materials are run through an air separator (where drying takes place by heated air from a furnace) which allows the proper size fines to be pneumatically pumped to the dry mixing and blending silos and recycles the oversize material back to the grinder. The blended mix is then pneumatically conveyed to the ground raw material storage silos from which the material is introduced into the kiln. In both processes, the slurry or dry mix is fed into the elevated end of the kiln. Firing takes place at the opposite end of the kiln, giving a heat flow counter to the material flow. The fuel can be powdered coal, oil, or gas. The raw mix is burned to partial fusion (to produce a cement clinker) at 2700°F, air cooled, proportioned with gypsum, ground in the same manner as the dry mix process and stored in bulk silos for ultimate bagging or bulk shipment.

The heart of the cement plant is the cylindrical rotary ceramic lined kiln which is also the largest single source of dust emission in the entire operation. Kilns range in size from 6 feet in diameter and 60 feet in length to 25 feet in diameter and 760 feet in length.(2) The kilns revolve on huge roller bearings and slope from the feed end down to the discharge and firing end at the rate of from 1/2" to 3/4" per lineal foot of kiln.

Basic operations employed in cement plants are crushing and grinding, blending, materials handling, clinker production and cooling, and fuel preparation for coal fired plants. Figure 7.10.1 depicts the sequence of operations and major differences between the wet and dry processes.(3)

C. EMISSIONS AND CONTROLS

Every operation in the cement production process, by its nature, produces dust. Dust fall measurements made in the Lehigh Valley in Pennsylvania, near plants using modern air pollution control equipment have recorded a dustfall rate of 35 tons/sq. mi./month. This area has a high concentration of plants producing 31,000,000 bbl/year of cement. Even with collection efficiencies of 90%, as much as 10 tons/day of dust can become airborne from a 4000 bbl/day plant attributed to the heavy grain loading of the kiln gas.(2)

Test data(4) of dust emissions from cement kilns are:

- Wet process - dust from kilns is 1 to 33% of finished cement (4 to 124 lbs/bbl).

  Arithmetic average of dust loadings in exhaust gases is 10.1% of the finished product.

- Dry process - dust from kilns is 1 to 25% of finished cement (4 to 94 lbs/bbl).

  Arithmetic average of dust loadings in exhaust gases is 11.3% of the finished product.

Technological changes for processing equipment will probably be concentrated in recycling collected kiln dust which may affect firing rates and the shape of the kiln. Increased collection efficiency of air pollution control equipment to 99.5% + is essential to reduce kiln dust emissions. Figure 7.10.2 presents the representative dust loading of kiln gases from the wet and dry process in kiln dust in exhaust gases.(2)

DUST LOADING CHARACTERISTICS

Kiln Type	Dust Loading[a] gr/ft^3
Wet	1 to 13
	10 to 13[b]
Dry	1 to 12
	20 to 55[b]

[a] Before collection at stack conditions (400 to 600°F)

[b] New long kiln utilizing chains and/or lifters

Figure 7.10.2. EXAMPLE OF CHARACTERISTICS OF KILN DUST (SOURCE: SUSSMAN, Reference 2)

Most of the sulfur dioxide formed in cement kilns as a result of the combustion of fuel is recovered as it combines with the alkalies. Tests of a coal fired kiln burning 2.8% sulfur coal showed a range of 6 to 39 ppm SO_2(4). There is no test data available on NO_X production but its formation is a distinct possibility with kiln temperatures in excess of 2600°F. Hydrogen sulfide and polysulfides may also be produced during drying of slurry or in the dry process when marl, sea shells, shale or clay are the materials processed.

Processing controls vary with the age and size of the plant. Kiln temperatures, which have a bearing on the firing rate and the raw mix feed rate, are indicated and usually recorded. Combustion equipment and controls will also vary; however, plant operators may be able to provide information even though data recording equipment may not be available.

A variety of dust control equipment is in use including bag type collectors, electrical precipitators, and multiclones. Generally electrical precipitators are used to collect the dust entrained in the kiln effluent because of the high temperature of the exhaust gas. Baghouses using glass fabric bags have shown efficiencies of 99.5%+(4) and should find increasing use in this industry. Dusts resulting from storage (silos are under positive pressure due to air displacement in loading or from pneumatic conveying), grinding, cooling and materials handling are usually controlled by bag type collectors or mechanical collectors.

Figure 7.10.3 represents a flow diagram of a cement plant which indicates the points of dust emission. The kiln which is the primary dust source is usually vented to an electrical precipitator or baghouse. Screens, mills, storage bins, and packaging facilities are generally vented to mechanical collectors and baghouses in series. Transfer points, drop points, elevator boots and loading stations should be hooded and materials collected. Depending on cross drafts and physical shape, hood design inlet velocities of 200 ft/min or more may be required.

In coal fired plants, pulverizing systems are used to prepare the coal for burning in the kiln. While the pulverizing system is "closed" and uses mechanical separators as part of the system, this ancillary process can also produce large quantities of dust.

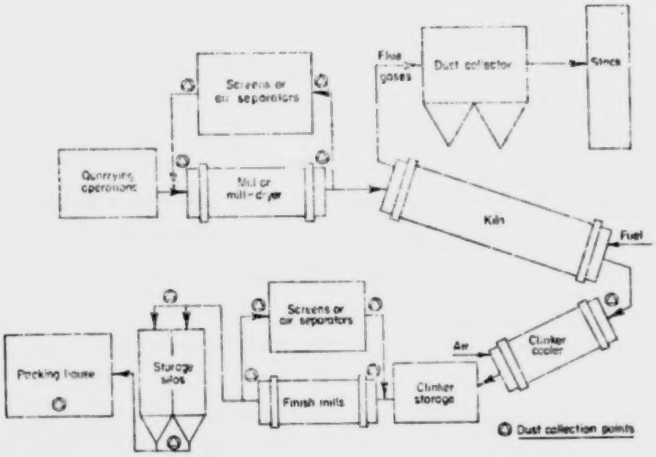

Screens or air separators
Flue gases
Dust collector
Stack
Quarrying operations
Mill or mill-dryer
Kiln
Fuel
Screens or air separators
Clinker cooler
Air
Packing house
Storage silos
Finish mills
Clinker storage
Dust collection points

Figure 7.10.3. FLOW DIAGRAM OF CEMENT PLANT OPERATIONS (SOURCE: SUSSMAN, Reference 2)

D. INSPECTION POINTS

The inspector should survey the plant to determine the adequacy of dust pickup at any location where dust is generated and, if necessary, request stack tests to determine the efficiency of the dust control equipment. The dust emission locations shown in Figure 7.10.3, except for the kiln, are at transfer points, size reduction equipment, classifying equipment (screens) and bulk loading facilities. Dust pickup efficiency of the hoods serving these areas is indicative of air pollution control performance. For example:

1. Good dust pickup means the system is operating at or near its design efficiency.

2. Poor dust pickup may mean plugged lines, air bleeding in through worn or damaged duct work, damaged fan, drive belt slippage or undersized motor.

Equipment and methods for field checking indraft velocities at hoods are described in Chapter 5.

The unmistakable sign of a cement plant is the plume from the kiln stack. Visible dust can be seen in the carry-over after the steam has dissipated. By comparison with previous observations, when the control device is known to have been operating effectively, the inspector can make a qualitative judgment as to the efficiency of the control equipment.

A check of the control room may provide evidence of malfunction of the equipment if there is a recording outlet opacity indicator instrument. The inspector will find it extremely useful to make notes of the recording and non-recording instrumentation which can include kiln temperature, fuel flow measurements and gas analyzers for combustion performance.

Electrical precipitators, for example, are sensitive to the temperature and moisture content of the inlet gases. Resistivity (resistance to relinquishing negative charge to the collection electrode) for most particles increases sharply when the gases entering the precipitator are between 200° and 400°F and less than 5% moisture (see Figure 7.10.4 and Chapter 2). Collection efficiency is adversely affected by low resistivity. The inspector thus should become familiar with the gas conditioning requirements of the precipitator and check the control instrumentation to see if the inlet conditions are in the proper range. The inspector should also check the rapping or washing cycle for removal of dust collected on the electrodes. Reentrainment of dust can occur if this cleaning function is not precise. Dust reentrainment can result in an increase in opacity of the effluent and a rise in the exhaust grain loading.

Baghouses using glass fabric filters are extremely efficient air pollution control devices for cement kilns. The major operational problem is to maintain the temperature of the gases in the baghouse above their dew point. Insulation of the baghouse enclosure, fan, and ducts is helpful in maintaining the proper temperature. Good operational procedures also require the exhaust fan to remain in operation during down time to prevent moisture buildup in the bags.

Inspection fundamentals apply regarding observations of equipment repair, non-use of dust collection equipment, and housekeeping. These should apply to roads and uncovered areas where dust has collected. Since the material is very fine, it can easily be disturbed by truck traffic and contribute to the background count of particulates for the area, as well as creating a public nuisance.

Dust collected from the kiln may be reinjected into the kiln, transported dry by materials handling equipment to a waste disposal area where it is dampened before it is dumped, or mixed with water to form a slurry and pumped to a waste pond.

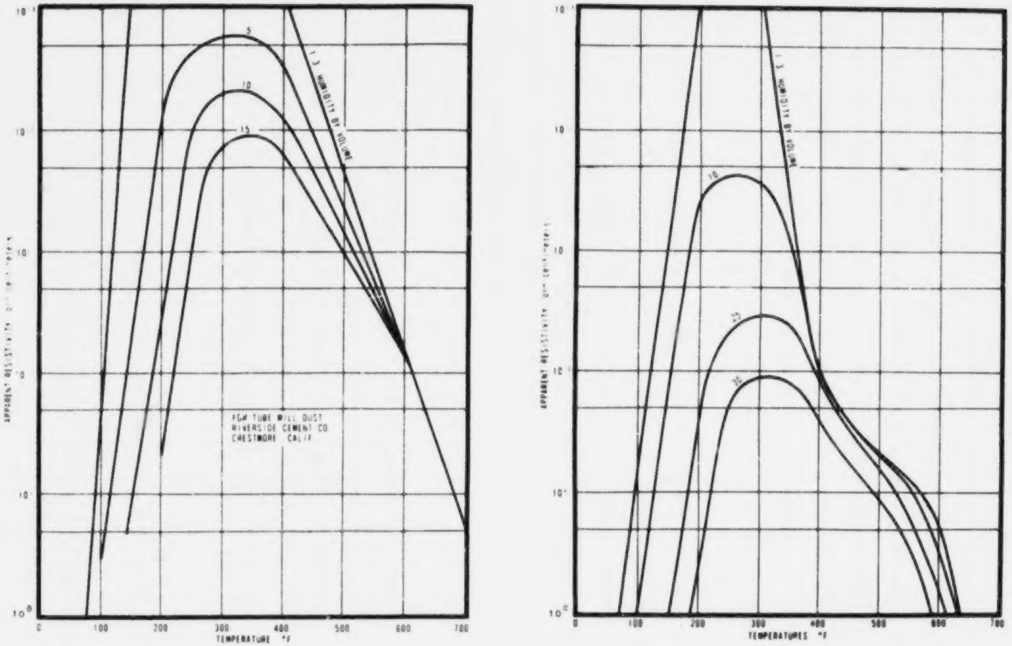


Figure 7.10.4. VARIATION OF APPARENT RESISTIVITY WITH TEMPERATURE AND MOISTURE FOR SOME TYPICAL DUSTS AND FUMES: (LEFT) APPARENT RESISTIVITY OF POWDERED LIME ROCK USED IN MAKING PORTLAND CEMENT; (RIGHT) APPARENT RESISTIVITY OF FUME FROM OPEN-HEARTH FURNACE (SPROULL AND NAKADA, 1951) (SOURCE: SIMON, Reference 5)

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XI. ALUMINUM REDUCTION PLANTS

A. DESCRIPTION OF SOURCE

Aluminum production consists of four major phases: Mining of Bauxite ore; alumina production consisting of ore refining, extraction and calcination of alumina ore (Al_2O_3); smelting or reduction of alumina to produce aluminum ingot or billet; and fabrication: processing of the ingot by casting, forging, extrusion, machining, rolling, drawing and other production techniques.

Mining and refining of alumina is mostly conducted abroad. Domestic refining is confined to Arkansas, Louisiana, Alabama and Texas and results in particulate pollution problems similar to the cement and lime processing industries, addressed in other sections of this Chapter. Fabrication and recycling or reclamation of aluminum products falls under the category of secondary metals production, treated in Section VIII. The aluminum smelting or reduction process is most significant from a domestic air pollution standpoint and will be treated in this section.

Approximately 30 major aluminum reduction plants are operated in the United States. These are generally located close to relatively cheap sources of electrical energy, particularly hydroelectric power. Additional power may be supplied from oil or coal-fired power plants. Principal plants are located in Alabama, Arkansas, Indiana, Kentucky, Louisiana, Maryland, Montana, New York, North Carolina, Oregon, Tennessee, Texas, Washington, West Virginia and Wisconsin.(1)

The basic process consists of the extraction of (elemental) aluminum from the refined alumina ore. Alumina is highly resistant to heat and chemicals due to the strong bond holding the atoms of aluminum and oxygen together.(2,3) Enormous amounts of electrical energy are required to separate these chemicals from each other. For example, the six aluminum reduction plants located in the State of Washington annually consume 2,000,000 kilowatts of electrical energy (equivalent to the entire generating capacity of Grand Coulee Dam) to produce 1,000,000 tons of aluminum, or 2 kilowatts for every ton of aluminum produced,(4) although newer plants are designed to be less power consuming per pound of aluminum produced.

B. PROCESS DESCRIPTION

From an air pollution standpoint the process of aluminum reduction can be seen in three phases: (1) handling of the alumina powders; (2) preparation of the carbon anode, and (3) aluminum reduction in pots or cells (see Figure 7.11.1). Two types of aluminum reduction processes are employed: prebake and Soderberg. These differ in the method of preparing the anodes required to effect electrolytic action in the pots. Prebake refers to the formation, pressing and baking of the carbon blocks prior to their placement in the pots. This may be conducted in a separate plant--the anode plant--which is usually operated within the same facility, less commonly at a plant at a different location. In the Soderberg process an anode paste mix of coke and pitch is added on top of the anode and is baked in place by the heat of the pot. The two processes, although they may be conducted at the same facility, dictate different pot and plant designs. These are discussed in greater detail in the following parts of this section.

1. Material Handling

Material handling involves transfer of the alumina powder in bulk from ship or rail cars to storage bins or silos located at the aluminum plant. Transfer is accomplished by bucket and conveyor systems, or by the use of vacuum lifters. Storage and transfer systems are likely to be enclosed, and in some plants exhaust systems and bag houses are applied to recover alumina losses. The alumina is

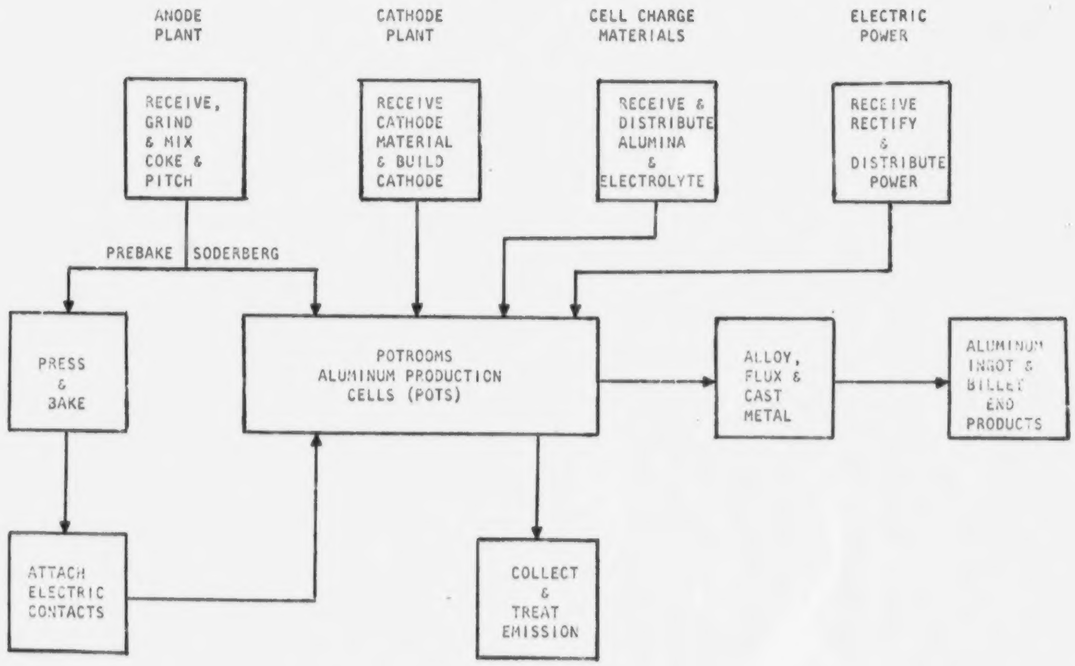

ANODE PLANT
CATHODE PLANT
CELL CHARGE MATERIALS
ELECTRIC POWER
RECEIVE, GRIND & MIX COKE & PITCH
RECEIVE CATHODE MATERIAL & BUILD CATHODE
RECEIVE & DISTRIBUTE ALUMINA & ELECTROLYTE
RECEIVE RECTIFY & DISTRIBUTE POWER
PREBAKE
SODERBERG
PRESS & BAKE
POTROOMS ALUMINUM PRODUCTION CELLS (POTS)
ALLOY, FLUX & CAST METAL
ALUMINUM INGOT & BILLET END PRODUCTS
ATTACH ELECTRIC CONTACTS
COLLECT & TREAT EMISSION

Figure 7.11.1. ALUMINUM REDUCTION PLANT FLOW DIAGRAM (SOURCE: STATE OF WASHINGTON, Reference 4.)

transferred from the inplant storage facility to silos in the potroom area, and hoppers are moved around the plant by overhead cranes or ground dispensing vehicles (see Figure 7.11.2). The dusts generated from the charging operation are collected by the ventilation hoods located on the pots or by a system covering the total building (called a secondary control system), although alumina dust will usually be found throughout the potroom floor area.

Alumina is a fairly dense particulate and usually will pass through a 325 mesh screen. Its white coloration makes leaks, emissions and spills easy to detect. Since alumina is highly inert, contamination resulting from spillage and floor deposits generally is not a problem and the material can be swept up and fed to the reduction pots.

2. Electrode Preparation

a. Cathode Preparation

The electrolytic process of aluminum reduction depends on the preparation and placement of the carbon anode (positive terminal) and cathode (negative terminal) in the pot of the furnace. The cathode consists of a pad of molten aluminum which forms over carbon blocks located on the bottom of, and perpendicular to the width of, the pot. The blocks are usually made from calcined anthracite. A carbon paste is rammed between the carbon blocks and baked in to seal the lining. During operation of the pot alumina dissociates electrically and molten aluminum deposits at the carbon cathode and oxygen aggregates at the anode and combines with some of the carbon anode to form oxides of carbon. Since the carbon cathode does not significantly deteriorate, it

Figure 7.11.2 not available for this publication.

may last for 2 to 4 years. Cathode operations are not significant from an air pollution standpoint except when they are being baked or removed. In the former, hydrocarbon emissions from binder materials will be produced and are collected by the exhaust system. In the latter, dust emissions may result from the process of removal (chipping away) of the carbon from the cold pot.

b. Anode Preparation

The anode is also made from petroleum coke, reclaimed anode carbon, and pitch or binding material. Since the carbon in the anode reacts with the oxygen liberated from the dissociation of alumina into oxygen and aluminum, it is gradually consumed and must be periodically replaced in the case of prebake, or added to in the case of the Soderberg pots.

In the prebake plant, carbon usually in the form of calcined petroleum coke is ground, blended with melted pitch (tar) and pressed into anode blocks, usually on a batch basis (see Figures 6.11.3, 7.11.4 and 7.11.5). Approximately 1/2 pound of carbon is required for each pound of aluminum produced. Spent anodes are also crushed and recycled in this operation. Wet collectors, e.g., Rotoclones, and other conventional collection equipment are used to collect dusts generated in this operation. Heat is supplied from a boiler plant.

The carbon anodes are block or tapered forms approximately 2 1/2 feet cube. The green anodes are conveyed by the overhead crane system and lowered into the ovens. The bake oven consists of a series of trenches and compartments lined with refractory brick. A number of trenches lie parallel to each other and run the length of the anode plant. The ovens are indirectly fired by means of gas or oil. Flue gas from the combustion equipment flows in chambers adjacent to the anode blocks.

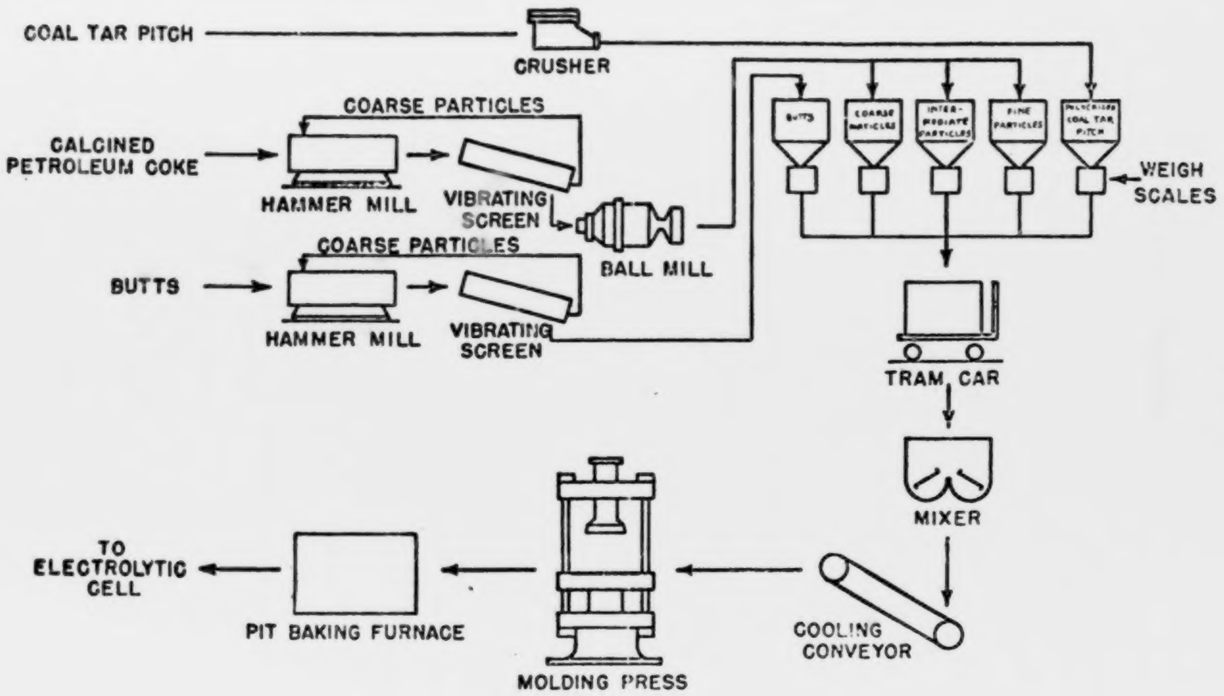

COAL TAR PITCH
CRUSHER
COARSE PARTICLES
CALCINED PETROLEUM COKE
HAMMER MILL
VIBRATING SCREEN
BALL MILL
COARSE PARTICLES
BUTTS
HAMMER MILL
VIBRATING SCREEN
BUTTS
COARSE PARTICLES
INTER-MEDIATE PARTICLES
FINE PARTICLES
PULVERIZED COAL TAR PITCH
WEIGH SCALES
TRAM CAR
MIXER
COOLING CONVEYOR
MOLDING PRESS
PIT BAKING FURNACE
TO ELECTROLYTIC CELL

Figure 7.11. 3. PREBAKED CARBON ANODE PRODUCTION PROCESS
(SOURCE: BLOCK AND MOMENT, Reference 1.)

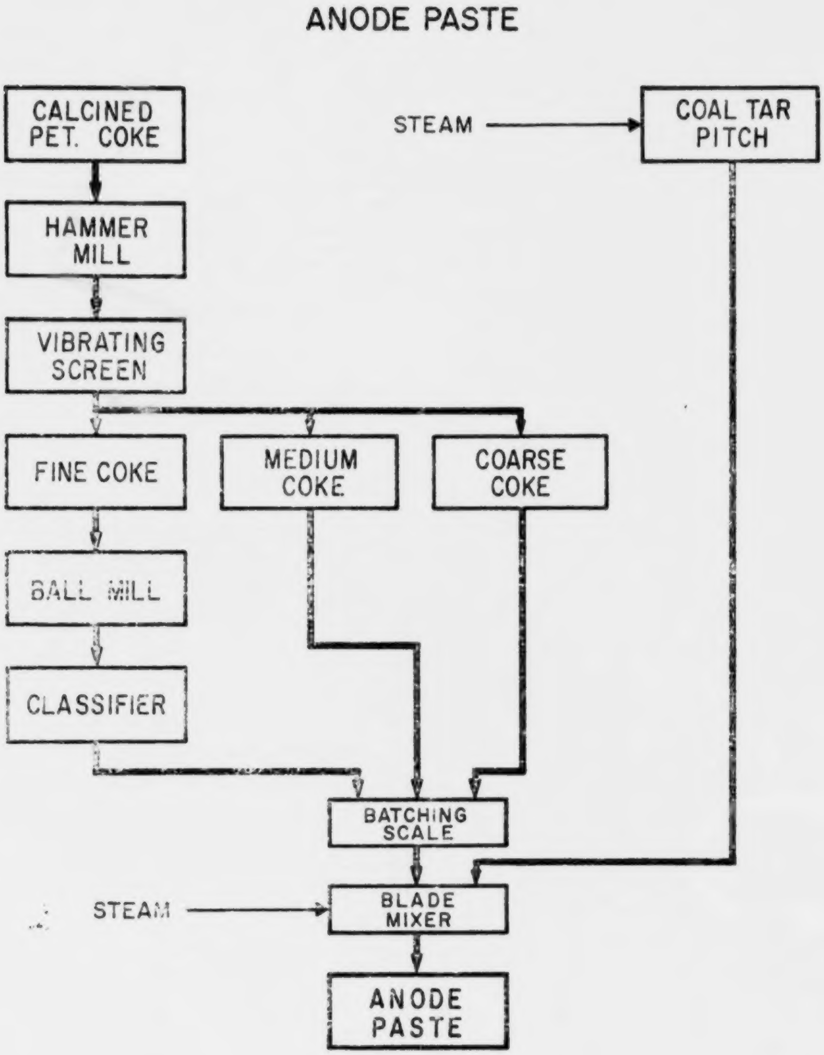

ANODE PASTE
CALCINED PET. COKE
STEAM
COAL TAR PITCH
HAMMER MILL
VIBRATING SCREEN
FINE COKE
MEDIUM COKE
COARSE COKE
BALL MILL
CLASSIFIER
BATCHING SCALE
STEAM
BLADE MIXER
ANODE PASTE

Figure 7.11.4. SODERBERG ANODE PASTE PRODUCTION PROCESS
(SOURCE: BLOCK AND MOMENT, Reference 1.)

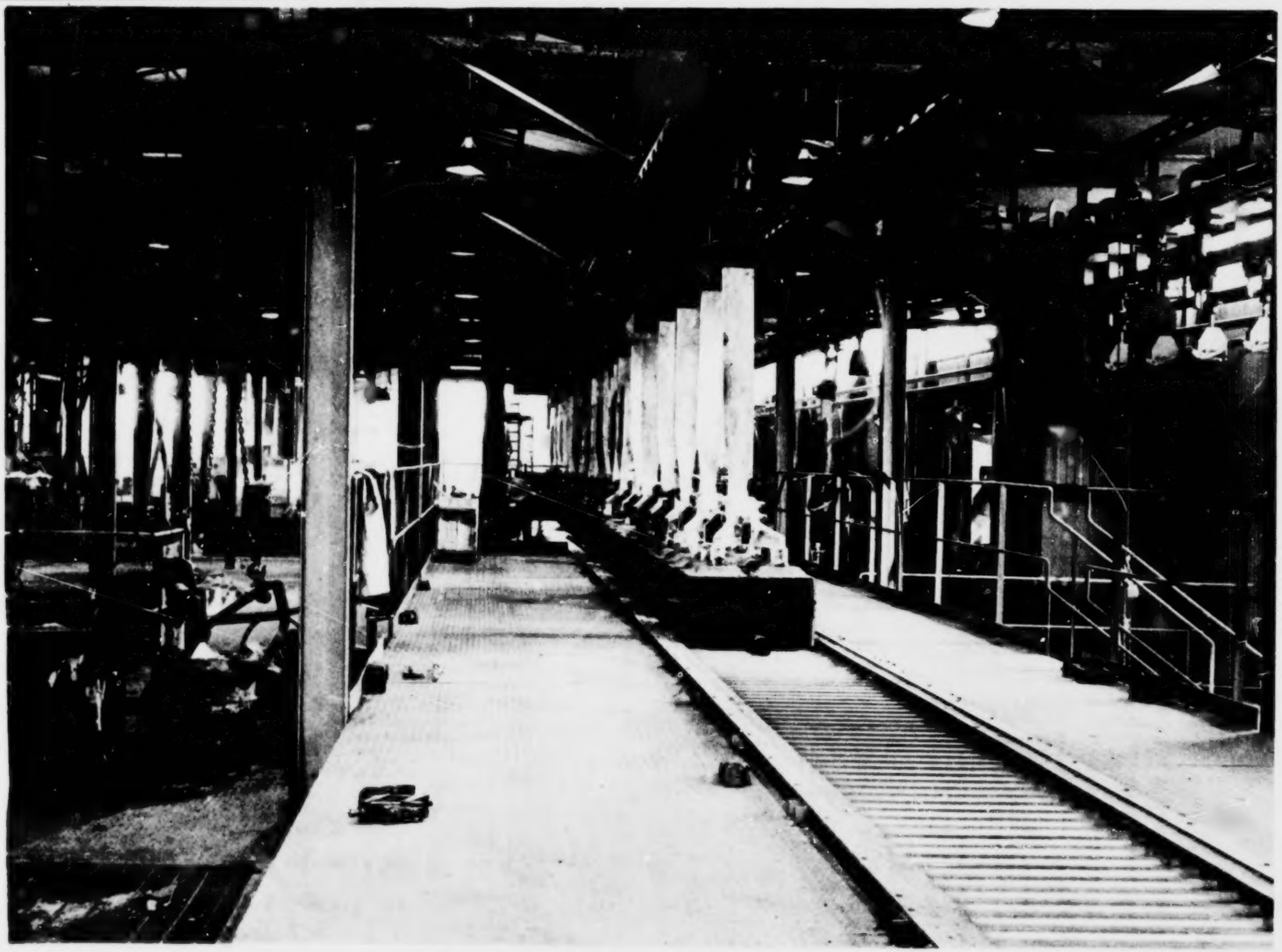


Figure 7.11.5. CARBON ANODES READY FOR USE IN ALUMINUM POTS (SOURCE: INTALCO ALUMINUM COMPANY, FERNDALE, WASHINGTON)

The ovens are preheated slowly to a maximum temperature of around 1400°F. and then cooled very slowly. The baking cycle may take approximately 2-3 weeks. The heating cycle is intended to achieve a durable anode with desired electrical properties, e.g., minimal electrical resistance, in order to maximize its service in the pot. Carbon monoxide, carbon dioxide, sulfur dioxide and particulates are emitted from the anode plant stack. After the anodes are baked, they are removed from the ovens, and steel pins are inserted and copper or aluminum connectors are attached. Anode assemblies may consist of 1-4 anodes. The anodes are conveyed to the potrooms where they are installed in the pots.

Emissions of dust and volatiles driven off the anodes, along with the products of combustion from the firing equipment are vented through a single and usually tall stack. Control systems, such as, high energy scrubbers, catalytic combustion or incineration can be employed. Emissions include sulfur dioxide contained in the coke fuel oil used, products of pyrolitic decomposition, including hydrocarbons, and some fluorides.

3. Potroom Operations

a. Prebake

The potroom constitutes the major source of pollution in an aluminum reduction plant. Smelting is performed in large rectangular pots or cells in which alumina, and the electrolyte are charged. The electrolyte is usually cryolite (sodium aluminum fluoride) and fluorspar (calcium fluoride). Raw materials required in the production of one ton of aluminum by both the prebake and Soderberg process are shown in Tables 7.11.1 and 7.11.2.

The cells are arranged in long pot-lines, and wired together in series (Figure 7.11.6). Direct current flows through a buss, through the carbon anode, the molten electrolyte and metal pad and out through

Table 7.11.1. RAW MATERIALS FOR THE PRODUCTION OF ONE TON OF ALUMINUM

Material	Amount (tons)
Sulfur	.01 = .05
Alumina (Al_2O_3)	1.9
Cryolite (Na_3AlF_6)	.03 - .05
Aluminum Fluoride (AlF_3)	.03 - .05
Fluorspar (CaF_2)	.003
Anode	
Petroleum Coke	.490 Prebake, .455 Soderberg
Pitch Binder	.123 Prebake, .167 Soderberg
Cathode (Carbon)	.02
Total: Approximately	2.6 tons raw material/ton Al

(SOURCE: HANNA, Reference 6.)

Table 7.11.2 COMPARISON OF REQUIREMENTS FOR PREBAKED AND SODERBERG SYSTEMS

	Soderberg	Prebaked
Time to produce one ton	37 hours	27 hours
KWH to produce one ton	15,400	13,600
Effluent gas treated per 100,000 amperes	4,000 CFM	23,500 CFM (no hoods) 4,000 CFM (hoods)
Scrubber water	$\frac{3.3 - 4.4\ \text{Gal}}{1{,}000\ \text{CF}}$	$\frac{10\ \text{Gal}}{1{,}000\ \text{CF}}$

(SOURCE: HANNA, Reference 6.)

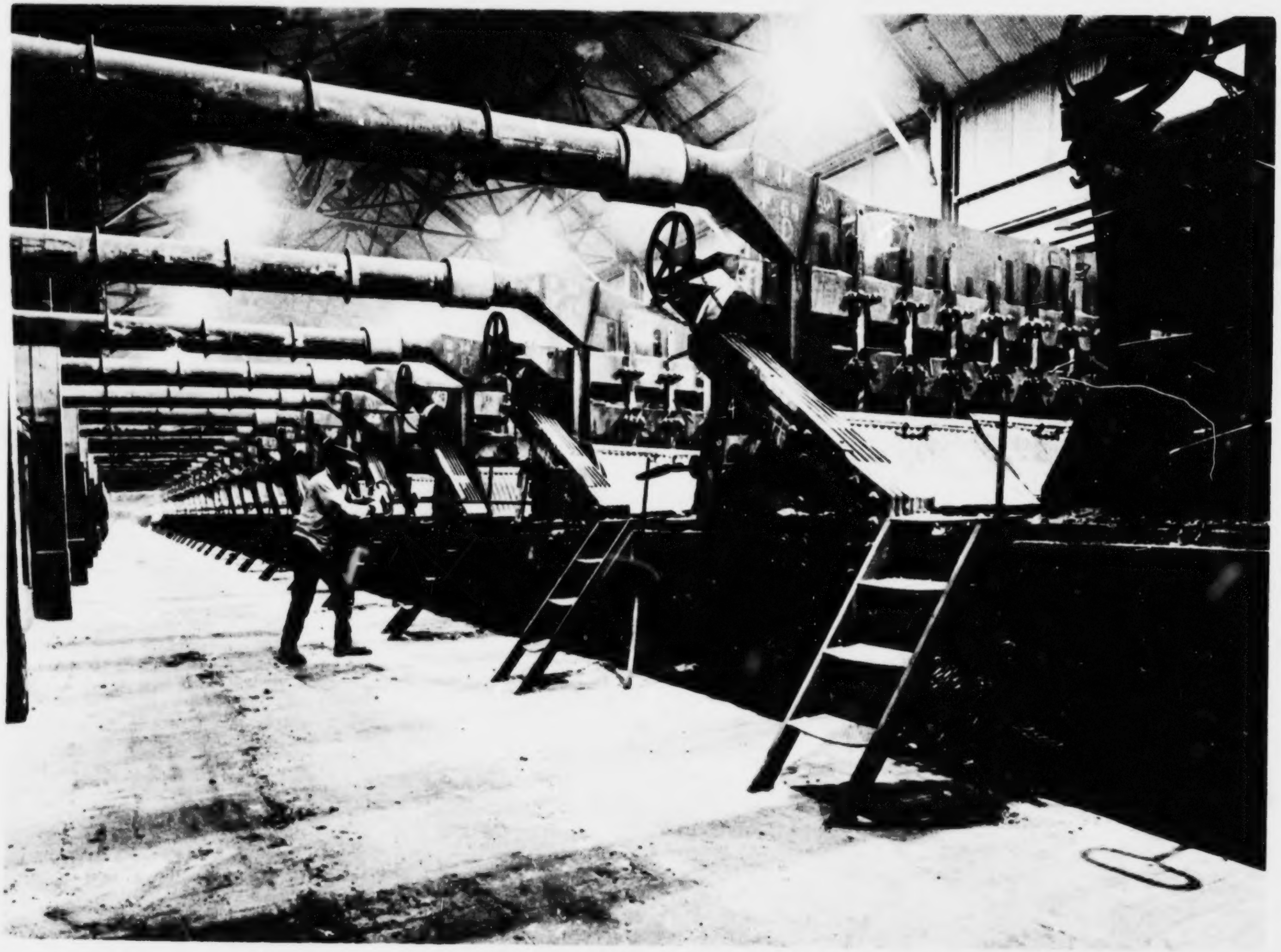


Figure 7.11.6. POTLINE, SHOWING ANODES SUSPENDED IN POTS, SPOKANE, WASHINGTON (SOURCE: KAISER ALUMINUM AND CHEMICAL CORPORATION, OAKLAND, CALIFORNIA)

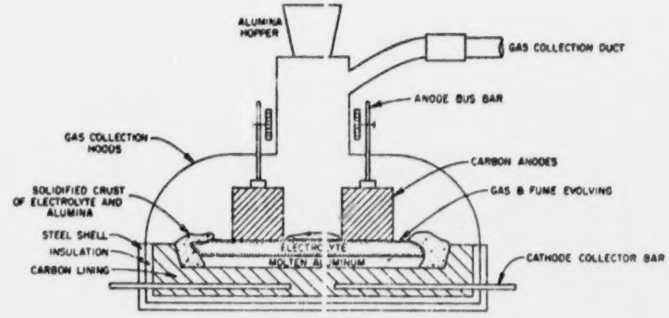
the carbon cathode linings of the cells. The current is characterized by low voltage (around 4.5 volts) and high amperage (about 50,000 to 200,000 amps). The temperature of the molten bath will reach 1742°-1792°F. The molten metallic aluminum forms a layer above the carbon lining of the pot and below the molten bath (see Figure 7.11.7). The oxygen liberated by electrolysis reacts with the carbon anode to form CO and CO_2. Hydrogen fluoride gas from the cryolite and particulates are also released. Emissions from the pots are collected by removable hoods or shields and vented through ductwork to a scrubber, an electrical precipitator, a fluidized bed, a baghouse or limited combinations of these devices.

The alumina is charged by breaking the crust (the frozen alumina and bath material) and laying on a fresh charge of alumina. This procedure is necessary to minimize thermal shock and prevent the addition of moisture. Gases, fine dust and fumes escape from the molten bath and if not picked up by the ventilation hoods enter the workroom and eventually the outdoor atmosphere.

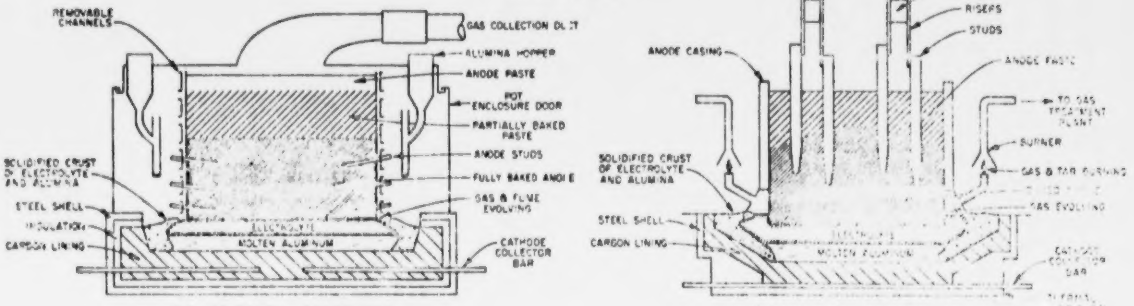
b. Soderberg

In the Soderberg process, briquetted coke and pitch is charged from hoppers on top of the anode structure by means of a crane, which moves down over the pot line. The prebake operation is thus eliminated, and baking emissions are captured by the ventilation hoods. The design of control equipment, particularly electrical precipitators, in the Soderberg process must take into account the tarry emissions, that is, collection of wet particulates in the precipitator.

Two types of Soderberg cells are in use: side pin or horizontal stud and verticle stud (see Figure 7.11.7). In the former, electrical connection is made by steel pins or studs inserted horizontally into the side of the anode through movable steel channels.(7) In the latter, electrical


ALUMINA HOPPER
GAS COLLECTION DUCT
ANODE BUS BAR
GAS COLLECTION HOODS
CARBON ANODES
GAS & FUME EVOLVING
SOLIDIFIED CRUST OF ELECTROLYTE AND ALUMINA
STEEL SHELL
INSULATION
CARBON LINING
ELECTROLYTE
MOLTEN ALUMINUM
CATHODE COLLECTOR BAR

(a) PREBAKED


REMOVABLE CHANNELS
GAS COLLECTION DUCT
ALUMINA HOPPER
ANODE PASTE
POT ENCLOSURE DOOR
PARTIALLY BAKED PASTE
ANODE STUDS
FULLY BAKED ANODE
GAS & FUME EVOLVING
SOLIDIFIED CRUST OF ELECTROLYTE AND ALUMINA
STEEL SHELL
INSULATION
CARBON LINING
ELECTROLYTE
MOLTEN ALUMINUM
CATHODE COLLECTOR BAR
BUS BAR
RISERS
STUDS
ANODE CASING
ANODE PASTE
TO GAS TREATMENT PLANT
BURNER
GAS & TAR BURNING
GAS EVOLVING
SOLIDIFIED CRUST OF ELECTROLYTE AND ALUMINA
STEEL SHELL
CARBON LINING
ELECTROLYTE
MOLTEN ALUMINUM
CATHODE COLLECTOR BAR

(b) HORIZONTAL SODERBERG

(c) VERTICAL SODERBERG

Figure 7.11.7. DETAILS OF PREBAKED AND SODERBERG ALUMINUM REDUCTION CELLS (SOURCE: ROSSANO AND PILAT, Reference 5,)

connection is made by steel pins or studs inserted vertically into the top of the anode. The anode is contained in a rigid casing open at the top and bottom. The vertical stud has the advantage that the off gases from the cell can be collected on a concentrated low volume basis by a collecting skirt attached to the bottom of the anode casing. The volume of off-gases is approximately 1/10 of that by prebake or horizontal pin methods. CO and combustible gases are passed through burners and fumes are drawn off by ducts and fans to a control device, which may include low and high energy scrubbers, electrical precipitators and a fluidized-bed baghouse combination.

C. CONTAMINANTS EMITTED

The obvious sources of pollution from aluminum reduction plants are the stacks from both the anode plant (in prebake facilities) and potroom exhaust systems and the potroom air vents and roof monitors. The tall stacks, which may be approximately 500 feet in height, are intended to disperse pollutants and to minimize downwind concentrations of contaminants and resultant fluoride damage. The plumes, however, are long and concentrated, and hence visible from many miles away. Other sources include vents, floor operations, control equipment (particularly scrubbers in older plants) and others.

Types of emissions related to plant operations are shown in Table 7.11.3 and fluorine and SO_2 emissions corresponding to various plant capacities are shown in Tables 7.11.4 and 7.11.5.(8)

The emission of hydrogen fluoride is most significant. The fluoride ion exhibits strong acid properties and can act as a protoplasmic poison. It can damage foliage at .1 parts per billion, accumulate in forage to 30-50 ppm on the inside and outside of leaves and can be fatal to livestock consuming contaminated forage.(9) Gaseous fluorides can be sampled by means

Table 7.11.3. EMISSION SOURCES AND CONTAMINANTS

EMISSION SOURCE OPERATION AND LOCATION	CONTAMINANT GASEOUS	CONTAMINANT PARTICULATE	TYPICAL CONTROL SYSTEMS
Cell operation Emission treatment exhaust (Soderberg only	CO_2, CO, CF_4 Hydrocarbons	Al_2O_3, AlF_3, Na_2CO_3, carbon dust Tar)	High energy scrubber Electrical Precipitator Fluidized bed Baghouse
Anode materials handling, grinding, classifying Building vents Dust collector exhaust		Carbon dust Pitch dust	Wet collectors Baghouse
Anode mixing Building vents Emission collector/treatment exhaust	Hydrocarbons	Carbon dust Pitch dust Tar	Wet Collectors Baghouse
Anode baking (Prebake only) Building vents Emission collector/treatment exhaust	CO_2, CO, SO_2, HF Hydrocarbons	Carbon dust Tars	High energy scrubbers Catalytic combustion Incinerators
Metal casting Building vents Emission collector/treatment exhaust	Cl_2, HCl CO_2, CO	$AlCl_3$, Al_2O_3 Cryolite	Operational flux and temperature controls
Cathode preparation Building vents Dust collector exhaust Emission collector exhaust	Hydrocarbons	Carbon dust Pitch dust Tar	High energy scrubber Electrical precipitator Fluidized bed Baghouse Roof scrubber
Alumina and electrolyte materials handling and distribution Building vents Dust collector exhaust		Al_2O_3, AlF_3 Cryolite, CaF_2, Na_2CO_3	Wet collectors Baghouse
Fugitive Dust Sources			

(SOURCE: STATE OF WASHINGTON, Reference 8.)
(Expanded)

Table 7.11.4. TOTAL F^- EMISSION - DAILY RATE AND CONTROL EFFICIENCY

PLANT	ALUMINUM PRODUCTION TONS	ELECTROLYTE CONSUMED		POTENTIAL F^- EMISSION		ESTIMATED F^- EMISSION		F^- CONTROL EFFICIENCY * %
		TONS	% OF PROD.	TONS	% OF PROD.	TONS	% OF PROD.	
1	480	28.5	5.9	14.9	3.1	2.16	0.45	85
2	274	18.0	6.6	9.6	3.5	1.82	0.66	81
3	575	31.6	5.5	16.5	2.9	2.94	0.51	82
4	220	11.5	5.2	5.7	2.6	1.52	0.69	73
5	720	41.9	5.8	22.8	3.2	4.56	0.63	80
6	520	7.6	5.3	14.0	2.7	2.92	0.56	79
Total per day:	2790	159	5.7	83.5	3.0	15.9	0.57	81
Average:	465	26.5	5.7	13.9	3.0	2.65	0.58	80

*Control efficiencies currently possible are in excess of 98 percent.

(SOURCE: STATE OF WASHINGTON, Reference 8.)

Table 7.11.5. TOTAL SO_2 EMISSION - DAILY RATE AND CONTROL EFFICIENCY

PLANT	ALUMINUM PRODUCTION TONS	ANODE COKE AND PITCH CONSUMED		POTENTIAL SO_2 EMISSION		ESTIMATED SO_2 EMISSION		SO_2 CONTROL EFFICIENCY **
		TONS	% OF PROD.	TONS	% OF PROD.	TONS	% OF PROD.	%
1	480	229	47.7	3.19	0.67	0.88	0.18	72
2	274	185	67.6	3.70	1.35	1.00	0.36	73
3	575	274	47.5	18.0*	3.08*	16.0*	2.8*	11*
4	220	122	55.5	2.44	1.11	0.92	0.42	62
5	720	358	49.8	6.72	0.94	1.85	0.26	72
6	520	286	54.9	3.56	0.69	0.80	0.15	77
Total per day:	2750	1454	52.2	19.6	0.89	5.45	0.25	72
Average:	465	242	53.8	3.92	0.55	1.09	0.27	71

*Not included in total and average values

**Control efficiencies currently possible are in excess of 90 percent.

(SOURCE: STATE OF WASHINGTON, Reference 8.)

of sampling trains using distilled water and solutions of NaOH as a collecting medium. Particulates are collected by filtration. Forage samples can be collected in inert containers such as a one quart glass jar or freezer bag. Water soluble fluorine compounds collected from ambient air are analyzed by use of ion-selective electrode methods and others.(10) Ambient air values can be quite low and expertise is needed to obtain reliable data.

The application of air pollution control methods in aluminum reduction plants will include improved basic equipment design, such as larger pot capacities, improved operations such as automating charging; improved hooding and collection efficiences; addition of controls to more emission points, such as the roof monitors.

Control methods for aluminum reduction cells include the following:

Wet Scrubbers. Spray towers can remove a high percentage of hydrogen fluoride since this contaminant is highly soluble in water. These devices, however, have a poor collection efficiency for fine particulates. Recent improvements include a floating-bed type of wet scrubber on horizontal Soderberg cells. This type of scrubber tends to overcome the problem of tar fouling that occurs in scrubbers with stationary packings.

Electrostatic Precipitators. Wet electrostatic precipitators are beginning to be used in controlling reduction cell emissions. These include vertical counterflow precipitators employing plywood collection plates which are irrigated with a falling film of water supplied from troughs at the top of the plates. Another application utilizes continuous spray washing of the collection plates and discharge electrodes.

Chemisorption. This process was introduced by the Aluminum Company of America (ALCOA) for treating gaseous and particulate fluorides.

The method consists of the chemisorption of hydrogen fluoride on a fluidized bed of finely divided alumina and removal of the sorbed fluoride by means of a fabric collector. Particulate fluorides are also removed by simple filters. The ALCOA system (Process A-398) requires effective local exhaust hooding on each pot (Figures 7.11.8 and 7.11.9).(5) Particulate emissions as low as 3 pounds of HF per ton of aluminum produced are claimed. Contamination of liquid streams and solid waste disposal problems are avoided. Spent alumina from the collector system is recycled to the pots and sorbed fluoride is added to the cryolite make-up.

Roof Collectors. In this procedure gases and dust are allowed to enter the workroom atmosphere. Large exhaust blowers at the ceiling (Figure 7.11.10)(5) induce an inward flow of outside air, through open louvres on the outside walls of the building, across the cells and into an overhead exhaust system to the gas cleaning equipment, usually wet scrubbing.

D. INSPECTION POINTS

Systems and equipment for controlling aluminum reduction emissions will require constant upgrading in the years ahead to meet increasingly stringent emissions standards. Emissions which may now range from 40-50 pounds/ton aluminum processed will have to be reduced to something like 15 pounds/ton and #1 Ringelmann. Bag filters and improved electrostatic precipitators may be the only types of control systems that will help to realize this goal. Such design improvements as larger pot capacities, automated ore feeding, and roof scrubbers should also help to achieve these goals.

Most of the inspector's function will be to help assure that compliance schedules are met, that control systems are conscientously operated and maintained, and plant facilities are operated and maintained in a manner which takes into account air pollution control, and prevents environmental damage in the vicinity of and downwind from the plant.

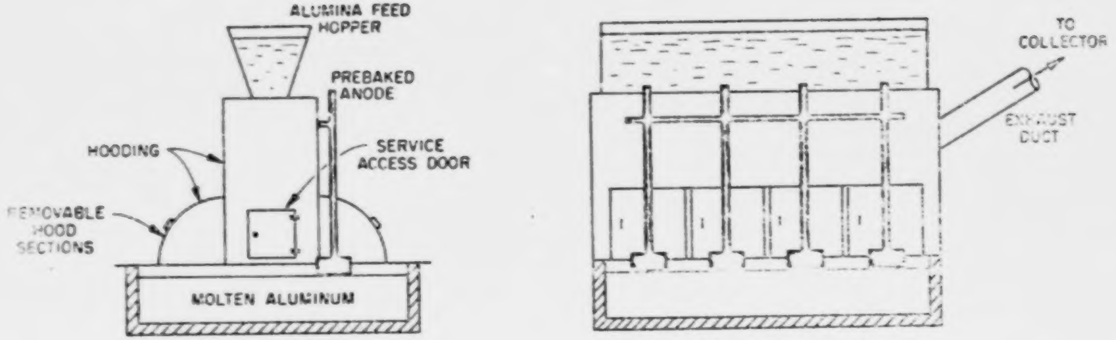

ALUMINA FEED HOPPER
PREBAKED ANODE
HOODING
SERVICE ACCESS DOOR
REMOVABLE HOOD SECTIONS
MOLTEN ALUMINUM
TO COLLECTOR
EXHAUST DUCT

Figure 7.11.8. SCHEMATIC OF ELECTROLYTIC CELL AS USED IN ALCOA A-398 PROCESS (SOURCE: ROSSANO AND PILAT, Reference 5.)

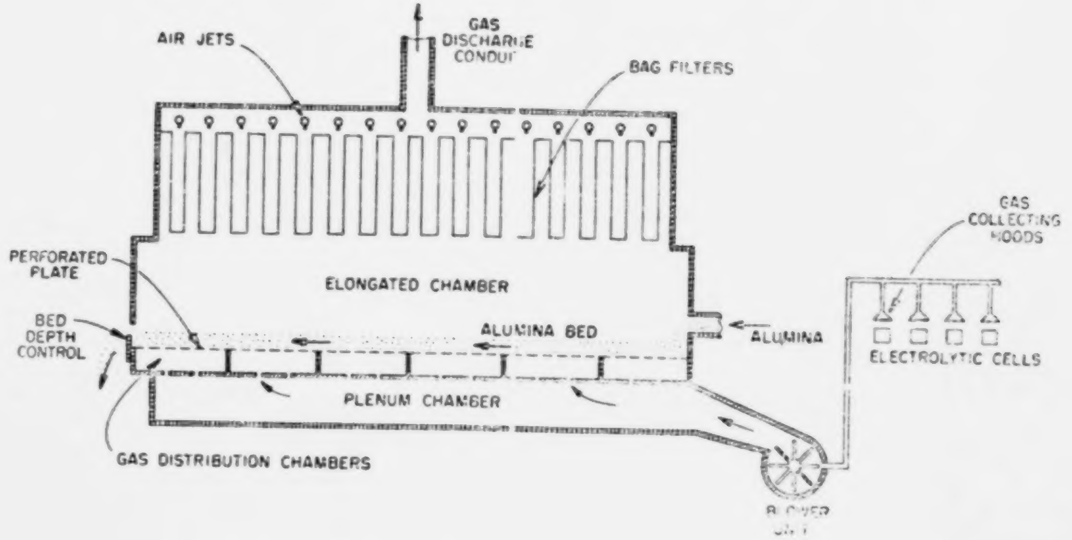

AIR JETS
GAS DISCHARGE CONDUIT
BAG FILTERS
PERFORATED PLATE
ELONGATED CHAMBER
BED DEPTH CONTROL
ALUMINA BED
ALUMINA
GAS COLLECTING HOODS
ELECTROLYTIC CELLS
PLENUM CHAMBER
GAS DISTRIBUTION CHAMBERS
BLOWER UNIT

Figure 7.11.9. SCHEMATIC OF ALCOA GAS CLEANING PROCESS. (A-398)
(SOURCE: ROSSANO AND PILAT, Reference 5.)

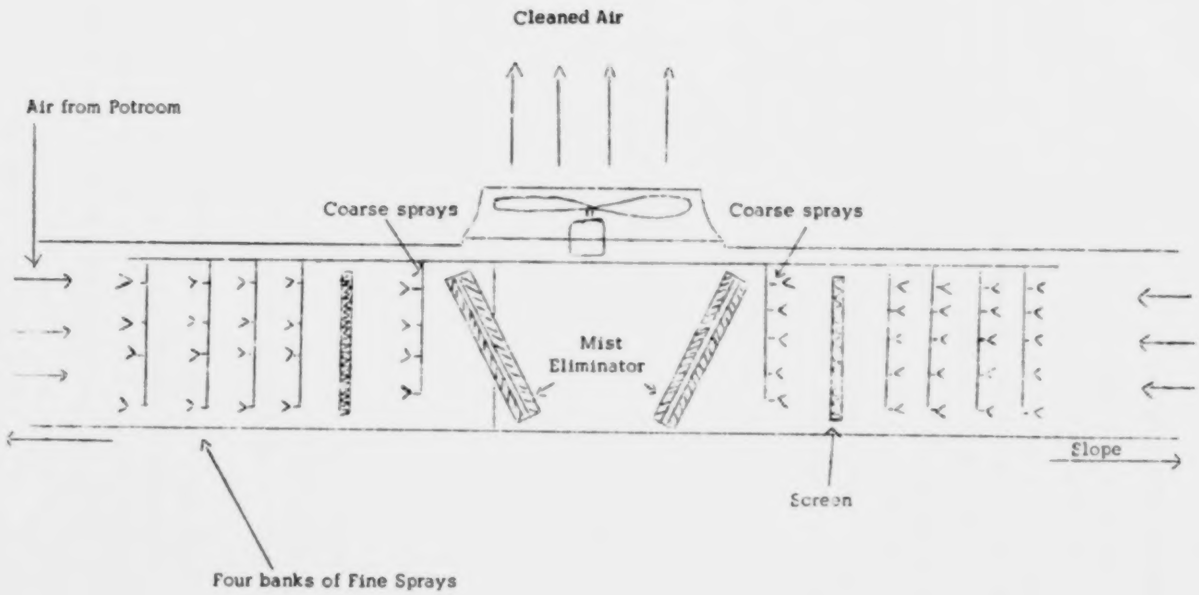

Cleaned Air
Air from Potroom
Coarse sprays
Coarse sprays
Mist Eliminator
Slope
Screen
Four banks of Fine Sprays

Figure 7.11.10. CROSS-SECTION OF ROOF SCRUBBER
(SOURCE: BYRNE, Reference 7.)

1. Environmental Observations

In the conduct of the inspection, the inspector should patrol, and tour on foot, the exterior of the plant looking for possible damage to forage and foliage. The type of damage that may occur varies with the species of vegetation. Any appearance of damage, particularly on margins and tips of leaves should be suspect and sampled. It may also be desirable to sample foliage that appears undamaged for analysis whenever there is reason to suspect that damage may be occurring. Samples should be taken in forage areas to ascertain the possibility of damage to livestock. Visual observations of livestock could also be made. In any event, if an inspector found something to suspect, a person with expertise in fluoride vegetation or animal effects should be consulted.

In selecting sampling points, prevailing winds and distances from the stacks should be taken into account. The following procedures(10) should be used in forage sampling:

- Cut the forage with a sharp knife or shears about 2 inches above the ground to avoid contamination by soil particles. Collect about 200 grams of sample; cut it into 1/4" to 1/2" pieces and store it in an appropriate container.

- Samples may be stored for up to 5 days before analysis, at refrigerator temperatures (5°C). Store the samples at 0°C or lower if they are to be kept for longer than 5 days.

- Care must be taken to assure that the sample represents the intake of the animal using the forage. In general, the sample should include the main species of forage vegetation in about the same proportion as they grow in the field.

- Do not take samples within 100 feet of any road unless it can be shown that road dust contamination is not a factor.

The following information must be included as part of the sample identification:

- Date of sample
- Time of day
- Location of sample
- Types and approximate proportions of vegetation in the sample.
- Weather conditions
- Any abnormal factor such as heavy traffic, construction in the area, harvesting nearby, etc.
- Original source of sample--is it stacked hay, baled hay, etc.
- Name of person who took the sample.

2. Exterior of Plant

The inspector should observe the exterior of the plant noting all emission points and the character of the emissions including the tall stacks, roof monitor emissions, scrubber outlets and other parts of the plant structure. In some locations, reading visible emissions from monitors may be approved procedure. Also, in some localities, background humidity readings, with the use of a sling psychrometer may be required (see Chapter 4). Scrubber outlets may have a tendency to contain a significant portion of dry fume in the emissions.

3. Interior of Plant

In the interior of the plant, the inspection should be organized around the initial alumina handling procedures, the anode plant and control systems (some plants may conduct both prebake and Soderberg operations), the potrooms, potroom control systems, and cast houses and other secondary metal operations. The inspector should note the following:

a. Firing system and fuels used in anode ovens, such as gas or oil, and the effectiveness and status of control systems.

b. General potroom emissions. The inspector should view down the potline for general inplant emissions, the degree to which emissions are expelled through the monitors and side vents, and handling of tapping and pot maintenance operations. The extent of emissions within the potrooms will give some idea of the general operational efficiency. HF is an eye and nose irritant, therefore, evidence of HF emissions could be detected by eye irritation or odor.

c. Collection efficiency of hooding in potrooms. When pots are opened to replace anodes, charge materials or to tap furnaces hooding efficiencies can be greatly reduced. The inspector should note how long the pots are open, and whether the hoods are damaged due to handling. Sometimes shields are pulled on 4-5 pots at a time. Automatic ore feeding employed in new plants may greatly reduce operational emissions.

d. Operational schedule of potroom. The inspector should become familiar with this schedule. The anode replacement schedule is usually equivalent to the anode baking schedule, in prebake plants. Cathodes are replaced less frequently, every 2 to 4 years depending on pot life.

e. Voltage readings on guages located atop each furnace. Voltages are relative to initial plant design, production schedules, etc. Generally, 4 to 6 volts is normal.

f. Pot performance. An anode effect is caused by the depletion of alumina and results in increased temperature, vapor pressure and fluoride and other emissions. If caught in time, the condition can be corrected by adding alumina, agitating the pot and/or adding more air. A sick pot results from too much alumina and causes a cold spot to form in the pot, a decrease in resistance, and an impairment of the electrolytic process. A light and a bell usually signal an anode effect and a sick pot respectively. The inspector could inquire about the rate at which these malfunctions occur per potline per day.

g. Performance characteristics and maintenance practices of scrubbers and other control equipment serving the pot ventilation system. The plant should also have the capability to by-pass to an alternative system, when it is necessary to shut down one of the control systems. The inspector should note capacities of scrubbers, special design features, such as mist eliminators and straightening baffles. The inspector should note the disposal of waste water from the scrubbers. High fluoride water should not be sent to rivers and lakes. United States Public Health Service standards require fluorine below 1 ppm if river is used for drinking supply. The inspector should also determine if pH adjustment of water is made in the scrubber.

h. Emissions from holding furnaces. The inspector should physically inspect all plant operations including cast houses and fabrication. Aluminum holding furnaces (see Chapter 7.8, part Cld) are used to remove air, organic matter and traces of metal as magnesium. The control of chlorine emissions from fluxing agents is poor or nonexistent at most primary aluminum smelters. Chlorine odor has a sweet, sickly odor and is easily noted when touring an aluminum plant.

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XII. MINING

A. NATURE OF SOURCE PROBLEM

Mining is the process of extracting mineral wealth from the earth, sea, or atmosphere. Since these mineral assets are not self-replenishing, it is important that they be collected in an efficient and non-wasteful manner.

The air pollution problem from mining operations involves primarily particulates from surface operations and combustion contaminants from fires. Additional pollutants are emitted into the ambient atmosphere via the ventilation systems of underground mines.

Mining often results in other forms of environmental pollution as well. Water contamination may occur as runoff passes through surface mining regions and into nearby bodies of water. This may have a very detrimental effect on the water supplies of downstream communities.

The condition of the land after mining is completed is becoming a major issue to conservationists. They are particularly critical of its ravaged appearance and apparent uselessness as a resource.

B. PROCESS DESCRIPTION

In order to remove natural resources from the ground, either underground methods and/or surface techniques may be employed. The character of the mineral deposits and the state of technology have important bearing on the procedure selected. In actual practice, it is more desirable to employ surface procedures for the following reasons:

- It is possible to recover deposits which often could not be retrieved by underground means.

- Safer and more healthful working conditions are provided miners.
- A more complete retrieval of the resource is accomplished.
- The cost per unit of production is less than with below ground methods.

Generally, surface mining is only possible if the thickness of the covering material (overburden) is small as compared to the size of the mineral deposit.

The utilization of below ground techniques requires extensive planning and consideration of a number of significant factors. Some of these include digging and supporting the mine, removing the resource, keeping the mine atmosphere healthful and free from the possibility of explosion, and other safety factors. Although proper planning is necessary for surface mining as well, the number of factors involved overall are far fewer and less critical.

1. Surface Mining

The surface mining methods producing the greatest air pollution effects are strip mining and open-pit mining. Strip mining is of primary importance in connection with coal. Open-pit mines are normally constructed in order to recover copper, iron and gypsum.

Regardless of the equipment or technique used, surface mining consists of the following steps:

- Site preparation--constructing access roads, designating dump sites, and clearing vegetation and other obstructions.

- Removal and disposal of overburden.

- Excavation and collection of the deposit.

- Transportation of the mined resource for processing.

a. Strip Mining

Strip mining is usually applied to recover coal deposits that are located near the surface of the earth. It consists of removing the overburden covering the mineral bed, and then loading the uncovered material.

Strip mining techniques are utilized on both flat and hilly terrain. On flat areas, a series of parallel cuts 40' to 150' wide are made in the surface. The overburden from the first cut is deposited in an area where no deposit exists (if possible). Thereafter, the overburden from one cut is deposited in the trench made by the previous cut. This process may be carried on systematically throughout the mining site.

If the area is hilly, the deposit may outcrop at the surface. In this case, the first cut is made at just above the exposed deposit with the overburden dumped further down the hill. As additional cuts are made, the overburden to be removed becomes thicker. It is piled next to the previous overburden in waste banks or spoil piles. These series of cuts continue until the overburden gets too thick as compared to the amount of deposit to be retrieved. Equipment utilized in strip mining consists mainly of bulldozers, draglines, and large power shovels.

The most serious air pollution problem in strip mining involves the extremely high combustibility of coal spoil piles. The spoil is stored in an area where the useful mineral is not being developed. Waste from coal cleaning and washing operations (see Section XIII) is frequently added to the piles. They are commonly ignited spontaneously or by burning rubbish close by or in strip pits. Once ignited, these waste banks may burn for decades emitting smoke and gases into the atmosphere and are very difficult, if not impossible, to extinguish.

A 1964 survey(1) counted 495 burning refuse piles in the United States. Often the burning piles are covered with some inert material to try to cutoff the oxygen supply. This practice only proves to be a temporary measure and the fire usually picks up again.

In the past, many methods to control fires, such as flooding, blanketing, slurry injection, and compacting have been attempted. However, a potential fire hazard will continue to exist unless the temperature within the spoil bank is maintained below the kindling point. Active burning is usually visible on the sides and bottoms of the spoil piles, where the large blocks of refuse generally tend to accumulate during dumping. Air is able to penetrate through the crevices formed by these blocks, is heated, and rises as if in a chimney. Changes in barometric pressure cause considerable air flows into and out of the pile.

The Bureau of Mines conducted a research program designed to aid the coal-mining industry in the control of burning refuse, and its disposal in a safe and economical manner. The Bureau studied the permeability of refuse, its spontaneous ignition tendency, and methods of extinguishing a burning pile of coal.

In field tests, the Bureau extinguished a five acre burning refuse pile in fifteen months. The technique involved decreasing the slope of the flank to approximately 30° and compressing the surface with a bulldozer. The pile was then covered with a three to five foot layer of minus 1/4-inch refuse material. A dike was constructed above the flank to prevent erosion. When the fire was determined to be out, the temperature of the pile three feet below the surface was less than 100°F.

In other experiments it was judged that minus 1/4-inch mesh refuse has little tendency to ignite spontaneously. In addition, under laboratory conditions it was found that four times as much air passed through 3 1/2-inch mesh refuse than through 1/4-inch mesh refuse.

Field investigations have shown that reducing airflow into the pile decreases the possibility of spontaneous combustion. Since most of the air enters the refuse pile through the flank, a dumping technique that reduces the flank area is preferred.

Although this technique has proved successful in testing, there is at present no indication how widespread its use is in practice, or how successful it has been.

Strip mining methods also often tend to liberate explosive gases such as methane, hydrogen sulfide, and acetylene. However, if allowed to be diffused into the atmosphere, the hazards due to possible explosion are eliminated. If the gases are trapped in any manner, the situation must be considered dangerous. The presence of hydrogen sulfide gas is easily detected by a strong odor of rotten eggs.

b. Open-Pit Mining

Open-pit mining is a common method used to extract consolidated ore deposits that are located at or near the earth's surface. These mines are generally cut into and around a hill or mountain, or are forged into the ground. They necessitate the removal of large amounts of overburden before actual deposit recovery may begin. Loose overburden is easily done away with, but all other rock must be excavated by combinations of the four principal operations of mining--rock drilling, blasting, loading, and haulage.

Drilling operations are employed to form blast holes. The type and amount of explosives used are governed by the character of the rock. Generally dynamite or ammonium nitrates are utilized. Loading is done by very large capacity power shovels and draglines. Haulage systems may utilize railroad cars, trucks, inclined skip hoists, or belt conveyors.

The system employed is determined by the depth of the pit, the production required, and the distance to the crusher or waste pile.

Open-pit mines are generally structured in benches or terraces. Each bench must be wide enough to carry trucks or railcars on tracks and not be buried in blasting operations. Sufficient space must also be available for large power shovels. Benches are usually between 20 and 76 feet in width. Fifty feet may be considered an average figure, with 30 feet regarded as a practical minimum. When the height of a face or bank exceeds a safe and practical limit, another bench must be created.

The general slope of the entire mine is measured by a line connecting the outer edge of the top and bottom benches. The height of each face and width of each bank must be such that the general slope of the mine considering all terraces is between 22° and 60°. However, since open-pit mines vary a great deal, slope criteria is extremely difficult to fix.

Open-pit mining methods are used to produce iron, copper, sand and gravel, gypsum, limestone and marble. The amount of overburden removed is small as compared to the amount of product recovered. In many cases, deposits are very thick resulting in a continuous mining activity for decades.

Some open-pit mines are difficult to distinguish from strip mines. This is especially true with certain brown iron ore and clay mines. Iron ore pits are generally quite large and quite deep. Lean, low-grade ore is often piled near the mine but is not responsible for very much environmental pollution.

Copper pits consist also of large openings. They are few in number and located in arid or semi-arid regions. Overburden and waste piles occupy large surface areas as well. Care must be taken to prevent their location above future ore reserves, yet close to the mine to reduce transportation costs. The waste piles may become a source of sedimentation and dust if preventive measures are not taken.

Frequently the waste pile contains small quantities of ore which is recovered by leaching. Leaching is the extraction of a mineral from an ore by selectively dissolving it into a suitable solvent as water or acified water. It is therefore desirable that the ground under the piles be impervious to leach water. Leaching is responsible for approximately 12% of recovered copper ore in the United States.

Sand and gravel pits are generally more disturbing to the general public than iron and copper mines. They are often located in or near urban centers where blowing dust, unsightly appearance, and noise are annoying problems, and steep banks are subject to dangerous slides. Other sand and gravel operations may be in the vicinity of streams. In these cases, significant amounts of sediment may be drained into the waterways.

2. Underground Mining

Distinctly subsurface deposits of minerals and ores are extracted by underground mining methods. Metal mining practices are similar to those used in coal mining except that the former are more diverse because of the more numerous variations in ore deposits.

The primary mine plans of operation are stoping and caving. In stoping, the ore-body is broken by drilling and blasting. There are various stoping techniques but the method selected is dependent upon the physical characteristics of the deposit in the mine, and economic and safety factors. Caving is often applied to large ore deposits with lower mineral content. A void is created below the ore-body, and then support is withdrawn from below. Possibly with the aid of blasting, the ore-body is collapsed allowing the ore to be drawn off. Another technique involves the caving-in of covering waste matter followed by the mining of the ore deposit from above.

In underground mines, special attention must be paid to the maintenance of safe and healthful working conditions for workers. Among the factors to be considered are mine support, explosives, air quality, and fires.

Except if included under state law, normal air quality requirements require the absence of smoke and dust with moderate air temperatures. In addition, coal mines require the elimination of methane. Good quality air does not contain harmful amounts of physiological or explosive contaminants.

The following gases are common to underground mines and should be expelled as contaminants.

(1) Carbon dioxide is produced by the combustion and oxidation of organic compounds. It is usually found in low, poorly ventilated areas.

(2) Carbon monoxide is not normally found in mine air. It is formed as a result of mine fires, or from gas or dust explosions, and the incomplete combustion of carbonaceous matter.

(3) Hydrogen sulfide is found near pools of stagnant water in poorly ventilated mine sections, and is the product of the decomposition of sulfur compounds.

(4) Methane is a natural constituent of all coals and may be found in metal mines as well. This highly explosive gas is often found in high, poorly ventilated cavities.

(5) Sulfur dioxide is commonly found only in sulfur mines. It is usually present after fires in rich sulfur ore mines.

(6) Black damp is a term used to describe oxygen deficient mine atmospheres that may contain many gases. It is produced by oxidation and processes that use oxygen and give off carbon dioxide.

In order to maintain mine safety, equipment is available to determine the presence of these contaminants in mines.

Dust in mines may be both a physiological and an explosive hazard. The incidence of various forms of pneumoconiosis (dust-related respiratory diseases) are common among miners, while coal dust presents an extreme explosive danger. Preventive measures include suppressing the dust with water, sprays, foam, or other agents.

Effective ventilation systems are required in mines in order to dilute mine gases and render them harmless, and to extract or collect dust particles from the mine. Various quantities of gas or dust may be expelled into the ambient atmosphere, but no data are presently available that will permit estimations of emission rates. Investigations should be conducted on this emission source.

C. INSPECTION POINTS

Because mining operations present health hazards to workers and are the basis of conservation issues, they are extensively supervised and inspected by other Federal and state agencies such as the Bureau of Mines and state divisions of mines. The purpose of this supervision is to minimize hazards related to physical injury and to occupational exposures to air contaminants within the mines (especially from CO, CO_2, SO_2, H_2S, methane, etc.).

The field enforcement officer is interested in mining activities from a number of standpoints:

1. Mines may be subject to equipment or activity inventory or source registration inspections. The enforcement officer therefore must become familiar with mine operations. All discrete surface and internal mine operations should be inventoried and described.

2. Dusts, smoke and organic emissions will occur from surface operations such as amassing spoil piles, loading and dumping, transportation activities and coal preparation (see Section XIII). The emissions and their sources should be surveyed, and notices written where indicated. Mine owners should prepare and submit source reduction plans.

3. Some mines will have greater emission potentials than others, due to the type of mine and nature of the deposits (e.g., sulfur deposits). Mine operational methods, products and capacities should be carefully shown on reports.

4. Ventilation systems should be checked and evaluated both from the standpoint of mine safety and emissions to the atmosphere from surface outlets. If necessary, air samples should be taken for analysis, or source tests conducted.

5. The enforcement officer should be aware of the hazards that may be present to himself and others.

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XIII. COAL PREPARATION PLANTS

A. DESCRIPTION OF SOURCE

Coal preparation plants clean, blend, size, dry and store raw coal which when mined contains 20 to 50% refuse material of undetermined size. Materials handling, sizing, drying and storage procedures and associated air pollution control problems are similar to those of many industries where large quantities of rock-like material are processed. Coal preparation plants also will play an increasing role in providing low sulfur coal in the future.

Air pollution control problems from coal preparation plants are sizeable. Among them are dust from the many drop points, conveyors and open storage piles; smoke, H_2S, sulfur oxides and other odors from burning refuse piles; particulate emissions from thermal dryers, de-dusters and other combustion related processes.

B. PROCESS DESCRIPTION

The preparation of coal for use by utilities or the metallurgical industry divides into two major air pollution control problems: (1) dust and particulate matter from the many mechanical and thermal processes in the plant and (2) gas, odors and particulates emitted from burning refuse piles.

Coal preparation plants vary in capacity and preparation methods. Common processes which create dust and particulates are cleaning processes, sizing, drying, refuse and storage.

1. Cleaning Processes

The principal reason for cleaning coal is to reduce ash content and some amount of surface sulfur. Sulfur, in the form of pyritic sulfur,

(sulfur combined with iron), organic sulfur (sulfur combined with coal) or sulfate (calcium sulfate) and mineral matter are present in raw coal. Ash-forming mineral matter can be removed by common cleaning methods but the inherent impurities--finely divided pyrite, organic sulfur and inherent mineral matter--cannot be removed.

The general cleaning methods in use in the United States are:(2)

- Cleaning at the mine face
- Separating impurities manually or mechanically
- Froth flotation
- Gravity concentration
  a. wet
  b. dry or pneumatic

Mechanical, strip and auger mining account for most of the coal mined in the United States. Manual cutting and loading in which the impurities in the coal are reduced at the source by selective cutting is still performed. This process is known as cleaning at the mine face. Increasing use of mechanical devices, however, has greatly reduced the need for this procedure.

The earliest method of cleaning coal, hand picking, is still practiced along with mechanical assistance from shake tables. After the initial screening operation, oversized coals, 4 inches and larger, are sent to the picking table where the impurities are manually removed from the stream coal. Picking facilities include belt and apron conveyors, shaking tables and occasionally chain conveyers. Since hand picking can leave as much as 50 to 60% coal in the refuse, it is economical to crush the refuse to reclaim the coal by mechanical means. An example of a mechanical device for removing flat impurities from coal such as slate and shale, which can be installed on shaker screens, is shown in Figure 7.13.1.

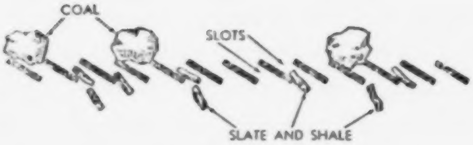

Figure 7.13.1. REJECTION OF FLAT REFUSE BY SLOT SHAKER
(SOURCE: THE BABCOCK AND WILCOX CO., Reference 2.)

Froth flotation supplements other cleaning processes by recovering coal fines from coarse coal cleaning. Flotation media may consist of alcohols and an added frothing agent. This process is most effective for 48 mesh and smaller material. The mixture is agitated by air injection with the coal particles adhering to the bubbles and the slate and shale sinking to the bottom of the vessel and removed as waste.

The principles of gravity concentration apply to wet and pneumatic systems for removal of impurities based upon differences in specific gravity (see Table 7.13.1). Wet systems in use in the United States(2) include:

- Launders
- Jigs
- Classifiers
- Dense-media method

Table 7.13.1. SPECIFIC GRAVITIES OF COAL AND IMPURITIES

Material	Specific Gravity
Bituminous coal	1.12 - 1.35
Bone coal	1.35 - 1.7
Carbonaceous shale	1.6 - 2.2
Shale	2.0 - 2.6
Clay	1.8 - 2.2
Pyrite	4.8 - 5.2

(SOURCE: THE BABCOCK AND WILCOX CO., Reference 2.)

a. Launders

In launders, shown diagramatically in Figure 7.13.2, coal is fed into a trough where high velocity water is introduced. The stratification of coal, middlings and slate occur in the steep section of the device. As the slope decreases the velocity of the mixture decreases allowing the heavier particles to settle and the cleaned coal to be removed.

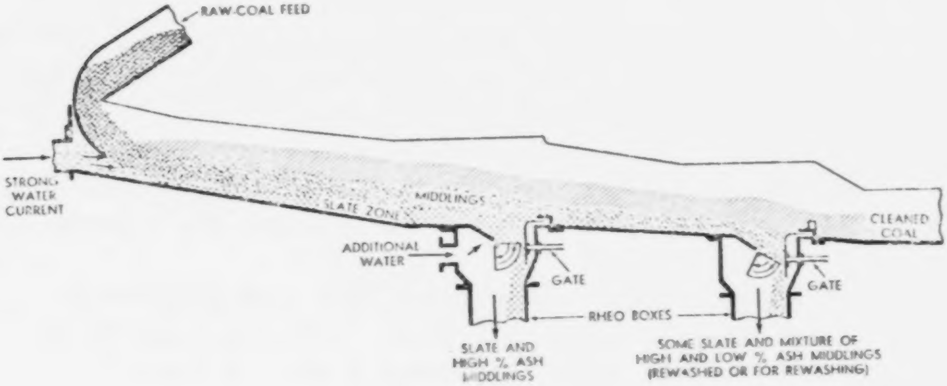
RAW COAL FEED
STRONG WATER CURRENT
SLATE ZONE
MIDDLINGS
CLEANED COAL
ADDITIONAL WATER
GATE
GATE
RHEO BOXES
SLATE AND HIGH % ASH MIDDLINGS
SOME SLATE AND MIXTURE OF HIGH AND LOW % ASH MIDDLINGS (REWASHED OR FOR REWASHING)

Figure 7.13.2. DIAGRAM OF RHEOLAVEUR COAL LAUNDER WITH TWO RHEOBOXES
(SOURCE: THE BABCOCK AND WILCOX CO., Reference 2.)

b. Jigs

Coal on screen plates is subjected to pulsating streams of water in a device known as a jig. The Baum jig, which uses air and water to produce pulsation can operate over a wide range of coal sizes while some types of jigs depend upon careful control of coal size in the feed for good classification results. An example of a Baum jig is shown in Figure 7.13.3. This system operates in two stages. Primary separation takes place at the feed end, while quality coal and middlings go to a second compartment where the quality coal is separated and the middlings are recycled.

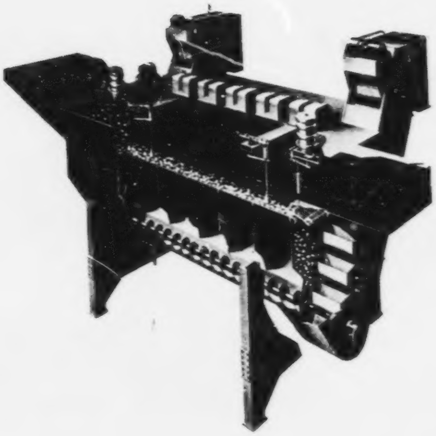

Figure 7.13.3. McNALLY NORTON STANDARD WASHER
(SOURCE: MC NALLY, Reference 3.)

c. Dense-media

The dense-media process uses a mixture of water and sand or magnetite, Fe_3O_4, proportioned to give the desired specific gravity to float coal and allow the waste material to sink. Figure 7.13.4 is a cross-section of a McNally Tromp Bath using the laminar flow principal to provide strata of equal density medium for uniform settling. Machines that provide more than one stage of settling, when required, may also be used.

d. Classifiers

Pneumatic classification systems process coal that has already been screened and is preferably low in moisture. Jigs and tables are used with air as the fluid instead of water. Air, blown up through the table suspends the lighter coal while the heavier waste material is caught in grooves between the rifles on the table bottom. The table is tilted and agitated so that the waste settles and the coal and middlings remain on top. The air used in this process is passed through cyclones and baghouses for fine dust collection.

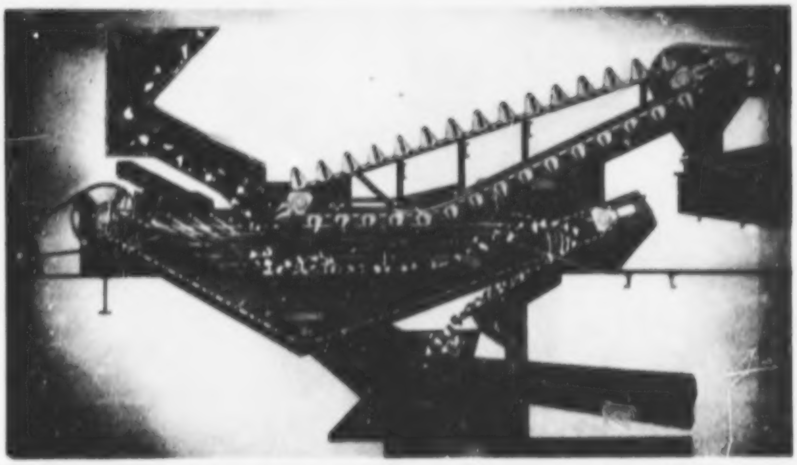

Figure 7.13.4. CROSS SECTION McNALLY TROMP BATH
(SOURCE: MC NALLY, Reference 3.)

De-dusting usually occurs after the raw coal has been screened. Coal dust rather than refuse is removed in this process. The dust clinging to the lumps falls free as the coal drops into the de-duster. A stream of air with a velocity high enough to entrain the dust--48 mesh--is forced counter to the flow of coal. The resultant air and coal dust mixture is run through cyclones and baghouses to remove the fines which can be loaded with the product or burned in any of the furnaces used in coal drying.

2. Sizing

Run-of-the-mine coal must be broken, sized and screened before cleaning or washing. These processes, along with handling, loading, storage and general housekeeping, account for most of the dust emissions from coal cleaning plants. Screen sizes generally conform to ASTM Standard D431, designating the size of coal from its analysis, but Bituminous coal sizes have not been well standardized. The following are common designations.(2)

- Run-of-Mine. Run-of-mine is shipped without screening. It is used for both domestic heating and steam production.
- Run-of-Mine (8 in.). This is run-of-mine with oversize lumps broken up.
- Lump (5 in.). This size will not go through a 5-in. round hole. It is used for hand firing and domestic purposes.
- Egg (5 in. x 2 in.). This size goes through 5-in. and is retained on 2-in. round-hole screens. It is used for hand firing, gas producers, and domestic firing.
- Nut (2 in. x 1-1/4 in.). This size is used for small industrial stokers, gas producers, and hand firing.
- Stoker Coal (1-1/4 in. x 3/4 in.). This size is used largely for small industrial stokers and domestic firing.
- Slack (3/4 in. and under). Used for pulverizers, cyclone furnaces, and industrial stokers.
- Several other sizes of bituminous coal are prepared by different producers, especially for domestic-stoker requirements.

Definite sizes of anthracite coal are standardized and shown in Table 7.13.2.

Table 7.13.2. COMMERCIAL SIZES OF ANTHRACITE
(Graded on Round-Hole Screens)
(SOURCE: The Babcock and Wilcox Co., Reference 2)

	Diameter of Holes, Inches	
Trade Name	Through	Retained On
Broken	$4\frac{3}{8}$	$3\frac{1}{4}$ to 3
Egg	$3\frac{1}{4}$ to 3	$2\frac{7}{16}$
Stove	$2\frac{7}{16}$	$1\frac{5}{8}$
Nut	$1\frac{5}{8}$	$\frac{13}{16}$
Pea	$\frac{13}{16}$	$\frac{9}{16}$
Buckwheat		
No. 1	$\frac{9}{16}$	$\frac{5}{16}$
No. 2 (Rice)	$\frac{5}{16}$	$\frac{3}{16}$
No. 3 (Barley)	$\frac{3}{16}$	$\frac{3}{32}$
No. 4	$\frac{3}{32}$	$\frac{3}{64}$

The broken, egg, stove, nut, and pea sizes are largely used for hand-fired domestic units and gas producers.

Buckwheat Nos. 1 and 2 are used in domestic stokers and hand-fired steam boilers. Buckwheat Nos. 3 and 4 are used for traveling-grate stokers, and No. 4 is also burned in pulverized form.

a. Breakers and Crusher

Size reduction is usually accomplished in two stages--breaking and crushing. Breaking the run-of-the-mine coal, removing rock and tramp iron is accomplished by a rotary equipment, such as the Bradford Breaker, shown in Figure 7.13.5. As the coal enters the perforated drum it is raised by the rotary motion (about 20 RPM) and falls breaking the lumps into smaller sizes that pass through the perforations. This process does not produce large quantities of fines.

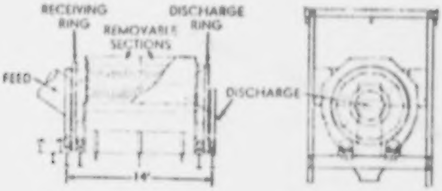

Figure 7.13.5. BRADFORD BREAKER, FOR USE AT MINE AND PLANT
(SOURCE: The Babcock and Wilcox Co., Reference 2)

The next class of equipment is crushers which, by mechanical action, further reduces the size of the coal. They are:

- Single Roll crushers which produce large quantities of fines--Figure 7.13.6.
- Double Roll crushers which produce small quantities of fines--Figure 7.13.7.

- Hammer-mill crushers which produce large quantities of fines--Figure 7.13.8.
- Ring coal crushers which produce large quantities of fines--Figure 7.13.9.

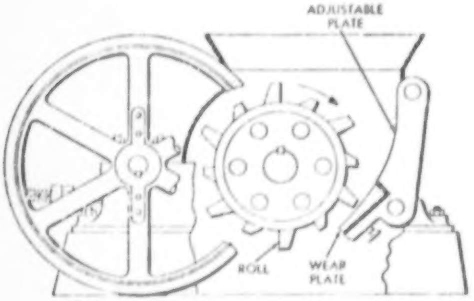
ADJUSTABLE PLATE
ROLL
WEAR PLATE

Figure 7.13.6. SINGLE-ROLL COAL CRUSHER--DIAGRAMMATIC SECTION
(SOURCE: The Babcock and Wilcox Co., Reference 2)

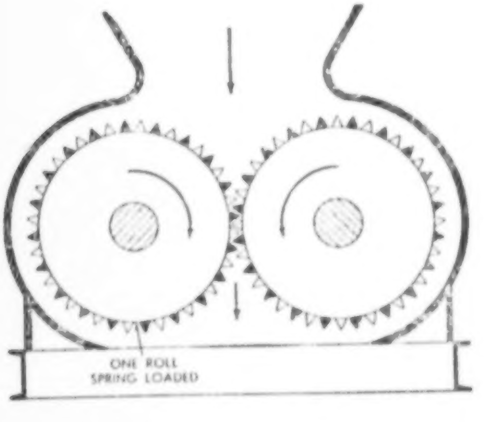
ONE ROLL SPRING LOADED

Figure 7.13.7. DOUBLE-ROLL COAL CRUSHER--DIAGRAMMATIC SECTION
(SOURCE: The Babcock and Wilcox Co., Reference 2)

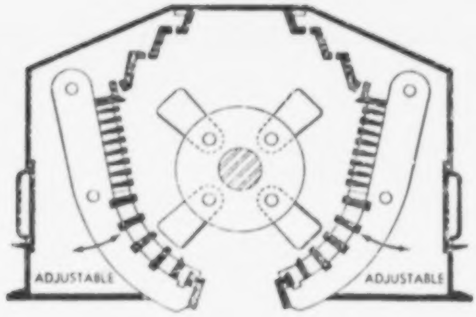
ADJUSTABLE
ADJUSTABLE

Figure 7.13.8. HAMMER-MILL COAL CRUSHER--DIAGRAMMATIC SECTION
(SOURCE: The Babcock and Wilcox Co., Reference 2)

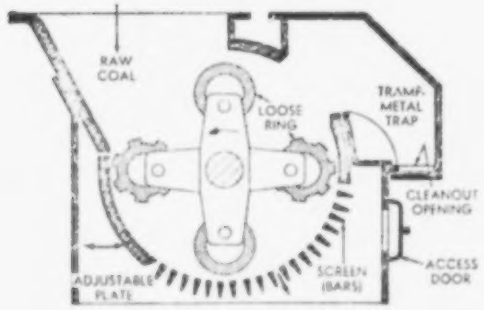
RAW COAL
LOOSE RING
TRAMP-METAL TRAP
CLEANOUT OPENING
ACCESS DOOR
SCREEN (BARS)
ADJUSTABLE PLATE

Figure 7.13.9. RING COAL CRUSHER--DIAGRAMMATIC SECTION
(SOURCE: The Babcock and Wilcox Co., Reference 2)

b. Screening

Screens provide another method of sizing. The bar screen or grizzly is used at the mines to size coal by gravity. The bars are sloped to allow the larger size lumps to traverse the screen while the smaller sizes fall through the openings.

Revolving screens are similar to rotating breakers except that they are inclined. Since the coal has a tendency to break in this type of action it is not customary to use coal sizes larger than 3 inches.

Shaker screens are usually sloped downward from the feed end to the discharge end. Again the oversize coal rides down the shaker and the desired size falls through the holes in the screen. This process is also used for dewatering washed coal.

Vibrating screens are also sloped from feed to discharge end. The high frequency vibration continually loosens the feed from the openings which aids in dewatering.

These processes produce significant quantities of fine dust. In addition to the use of local exhaust systems to capture dust, water sprays with wetting agents help to control emissions from these sources.

3. Drying

Mechanical drying or dewatering devices have been described above. The greatest single source impact on air pollution in coal preparation plants is thermal drying. Thermal drying is a process of accelerated evaporation. Unless the dry product can be kept below its critical ignition temperature of 130 to 150°F, fires will result in transit from spontaneous combustion. Coal dryers all use direct heat transfer where the combustion gases plus tempering incoming air come in direct contact with the material.

Five principal methods for drying coal used in the United States include:(4)

- Rotary dryers
- Screen type dryers
- Cascade dryers
- Suspension type dryers
- Fluid bed dryers

a. Rotary Dryers

The rotary dryers resemble kilns and may be parallel or counterflow (air and coal), single or double shell and louvre types. These are the older kind and better known to the trade. These cylindrical drums are pitched longitudinally about 3/8 inch per foot, causing the material to travel slowly from the feed to the discharge end. The drums may be 8 to 10 feet in diameter and 65 to 80 feet long. Lifting vanes drop the coal through the hot gases. The inner shell of the double shell type carries the hot gases to the discharge end of the dryer where they turn and reverse their direction in direct contact with the counter flow of the solids.

b. Screen Type Dryers

The screen type dryers carry the coal on reciprocating screens which accomplish evaporation by passing hot gases through the bed. These can be down-draft or up-draft; the down-draft type affords the opportunity of some mechanical drainage. These are designed for coal with top sizes up to 2 inches and a bottom size of 1/2 mm. On one model, an induced draft fan draws the hot gases down through the screen decks and the flow is automatically alternated so as to transfer the suction from the first to the second screen sections every second. This arrangement causes the full force of the gas pressure to squeeze the bed, thus accelerating mechanical drainage.

c. Cascade Dryers

Cascade dryers (Figure 7.13.10) accomplish their heat transfer by introducing hot gases through louvers which are arranged to cause the coal to cascade. The coal forms a curtain of flowing coal and hot gases are passed through it to impart heat for evaporation. This type is most widely used for fine coal (3/8 x 0) but coals up to 1-1/2 x 0 have been dried successfully.

Figure 7.13.10 not available for this publication.

d. Suspension Type Dryers

Suspension-type systems (Figure 7.13.11) introduce the wet coal into a moving hot stream of gases which pneumatically convey and dry the material in transit to the dust collector where the coal is separated from the moisture-laden spent gases. This class of dryers is ideal for extremely fine coal with the top size not over 3/8 inch.

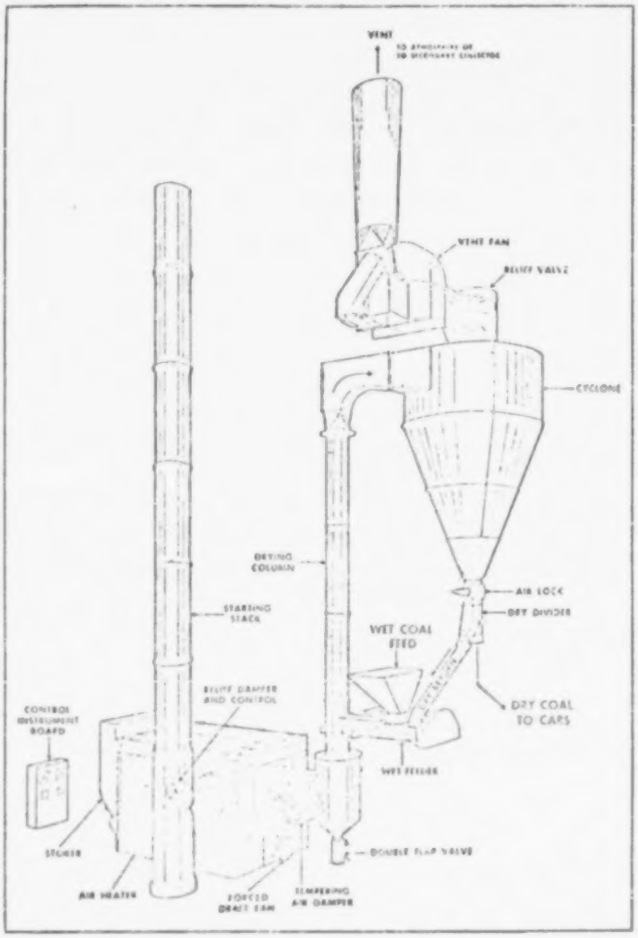
VENT
TO ATMOSPHERE OR TO SECONDARY COLLECTOR
VENT FAN
RELIEF VALVE
CYCLONE
DRYING COLUMN
AIR LOCK
DRY DIVIDER
STARTING STACK
WET COAL FEED
RELIEF DAMPER AND CONTROL
CONTROL INSTRUMENT BOARD
DRY COAL TO CARS
WET FEEDER
STOKER
DOUBLE FLAP VALVE
AIR HEATER
FORCED DRAFT FAN
TEMPERING AIR DAMPER

Figure 7.13.11. SUSPENSION-TYPE FLUSH DRYING SYSTEM (THERMAL DRYER)
(SOURCE: RAYMOND DIVISION, COMBUSTION ENGINEERING, CHICAGO, ILLINOIS)

e. Fluid Bed Dryers

In fluidized bed dryers (Figure 7.13.12) the wet coal is fed onto a perforated or bar type retention plate where hot gases are blown or drawn through the bed. Fluidized beds are characterized by a loose pulsating mass which is kept porous by the action of the gas stream.

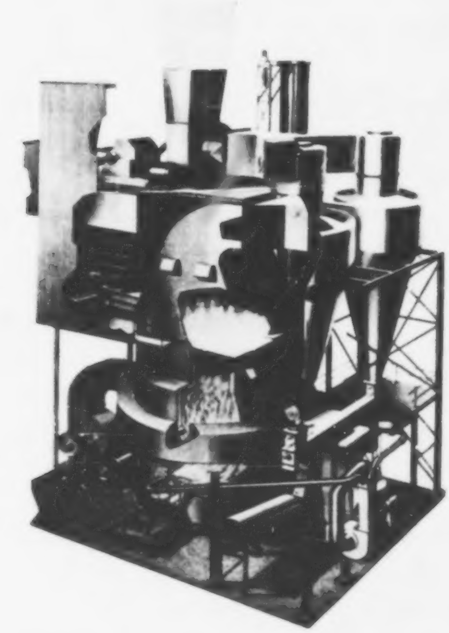

Figure 7.13.12. McNALLY FLOWDRYER
(SOURCE: McNally, Reference 3)

The air pollution control problem from coal drying does not differ from most drying operations where the hot products of combustion pass through wet material which contain fine particles of product. Coal is the primary fuel used to produce the hot gases which evaporate the moisture from the product (see Chapter 6, Section II). Fuel oil is used at some installations especially during startup operations. Primary dust collectors are cyclones followed by wet collectors and demisters. Conventional scrubbers have not proven effective on thermal dryers but high energy venturi scrubbers with demisters have reduced the grain loading in several installations from a high of 5.5 grains per standard cubic foot to 0.04 grains per standard cubic foot.(1) Baghouses are not used in these systems because of fire hazards.

4. Refuse

Coal refuse piles are a constant source of combustion and dust related air pollution control problems. Some of these piles cover acres of ground and contain hundreds of tons of material. Spontaneous combustion, carelessness or deliberate action are the general causes of refuse pile fires. Often trash not resulting from coal preparation contributes to the potential fire hazard at the refuse dump site. A survey made in 1964(1) indicates that there are approximately 500 burning piles in 15 states; approximately 150 in Pennsylvania and 200 in West Virginia. Emissions, in addition to blowing dust from the piles are H_2S, SO_2 and smoke. Other noxious gases which result from burning piles include CO, ammonia and carbon disulfide.

Air pollution control and safety measures include proper construction of the pile by compaction and sealing to prevent air circulation and ignition. Some methods of controlling a burning coal refuse dump are:(1)

a. Digging out the fire or isolating the fire area by trenching.

b. Pumping water onto the fire areas and immediate vicinity.

c. Applying a blanket or cover of incombustible material such as limestone dust, shale dust, or slag dust over the fire area.

d. Injecting a slurry of rock dust or other incombustible material into the fire area through drill holes. Grouting with cement is also practiced.

e. Spraying water over the area.

5. Coal Storage

Coal is stored in huge open piles and in silos or underground facilities. As in refuse storage there are two primary air pollution control problems, blowing dust and combustion products. Anthracite coal is very safe to store in large piles. These piles should be capped with larger sizes to prevent loss of fines due to wind.(2) Bituminous coal should be packed and sealed as a fire prevention technique. Promising tests have been made using water soluble organic polymer as a spray on outdoor piles of crushed coal to form a hard surface to reduce wind blown dust. Test piles have withstood winds as high as 60 MPH and numerous freeze thaw cycles.(5)

C. EMISSIONS AND CONTROLS

The largest single source of dust, smoke and particulates in coal preparation plants are the thermal dryers. Dust loading of the effluent from a dryer operating at 150°F, 180 to 120,000 cfm with the feed 1/4" centrifugal coal and filter coke, can be in excess of 2.5 grains per cubic foot with a particle size distribution of:(6)

0 to 2μ	55% by weight
2 to 5μ	33% by weight
5 to 10μ	11% by weight
10 +μ	1% by weight

Cyclone separators can eliminate high percentages of the larger particle sizes and serve as the first stage in a particulate recovery train. Dark brown emissions of 100% opacity are visible from plants using cyclones and low resistance scrubbers. Effective emission reduction from thermal drying requires, in addition to cyclones, pack towers or venturi scrubbers with demisters.

D. INSPECTION POINTS

1. Screening, Crushing and Breaking

Fines escaping from ventilation systems serving the equipment from these processes constitute a major air pollution control problem. The inspector can readily determine the effectiveness of sprays to suppress dust and hooding and local exhaust systems to pick up the dust generated. Exhaust systems and cyclones can become plugged by caking of fine coal which will add to the system back pressure thus reducing hood indraft velocity and reducing the cyclone collection efficiency.

2. Conveyors and Elevators

Long open conveyor belts carrying dry material or appreciable quantities of fines can be a significant source of dust. All drop points onto or off of open belt conveyors should be evaluated for dust emissions. Special attention should be paid to railroad car loading and dry coal storage activities.

3. Pneumatic Classifying and Dedusting

These processes use high velocity air streams which entrain sizeable quantities of fines which are collected by cyclones and a baghouse in series. An increase in resistance to flow caused by plugging the exhaust lines and dust collectors will cause a decrease in pickup from the ventilation system resulting in dust emissions or poor pickup of dust at the source. Since the material collected is a useable product the operator will make certain that the dust control equipment is properly maintained.

4. Thermal Drying

In order to determine the effectiveness of air pollution control equipment on thermal dryers, stack tests should be required. The inspector can determine if fine material, e.g., 48 mesh, is being used as furnace fuel which experience has shown contributes to the particulate emissions. Because of this, some operators intend to go to oil-fired furnaces full time.

E. ENVIRONMENTAL OBSERVATIONS

Dust and particulate matter will be found in areas adjacent to coal preparation plants when rigid air pollution control programs are not mandatory. Meteorological conditions will determine how far and in what direction fine dust particles will travel. If burning refuse is a problem, the probability of odor complaints will be high.

The inspector should determine the direction of the prevailing wind so that he may station himself properly to make readings from the dryer exhaust stacks. This will also help to establish a gross dust fallout pattern and a probable pattern for nuisance complaints. One method of making these determinations is to place dust fall jars at the plant property lines. In-plant observations should focus on housekeeping since there usually is an abundance of fine coal particles which can be disturbed and become air borne by the large volume of truck traffic in and out of the plant.

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XIV. FERTILIZER INDUSTRY

A. NATURE OF SOURCE PROBLEM

For the purposes of this chapter we will define the fertilizer industry as being limited to the chemical fertilizers. Only very limited amounts of fertilizer are derived from natural waste products at the present time in the United States and most of this originates from activated sludge plants operated in connection with municipal sanitary sewage treatment plants.

The practice of using fertilizers dates back to antiquity. As early as 200 B.C. the Carthaginians were said to have used bird dung on soil as a source of phosphatic materials.(1) Over the centuries replenishment in the soil of this essential element was aided by the use of bones, fish and bat and sea bird guano. In the nineteenth century a number of individuals experimented with methods increasing the solubility of the phosphate sources and in 1842 a British patent was issued to John B. Lowes on the process of treating bone ash with sulfuric acid.

The other two major constituents of fertilizers--nitrogen and potash--were also first used as natural waste products. Nitrogen sources included oil seed meals, fish by-products, tankage, and dried blood. Since the advent of chemical fertilizers these natural materials are more valuable as direct animal feed supplements. Potash was probably first utilized in the form of wood ash.

Present day compounds used as sources of phosphates, nitrogen, and potash result from the processing of minerals or from direct chemical synthesis. These manufacturing processes can produce a variety of gaseous and particulate air contaminants generally associated with the chemical fertilizer industry.

Two major sub-groupings of the chemical fertilizer industry are of particular importance as air pollutant sources and will be considered in more detail in this chapter. These are (1) the phosphatic compounds produced from phosphate rock and (2) ammonium nitrate produced by the reaction of ammonia with nitric acid.

1. Phosphate Fertilizers

The air pollutants emanating from the phosphate fertilizer industry are of two distinct classes: the first being particulates originating from the crushing, grinding, drying, and bulk handling of rock ore, beneficiated rock and product materials; the second being gaseous contaminants evolved during the acidulation and curing of phosphate rock to produce phosphoric acid, superphosphate and triple superphosphate. Other gaseous compounds may be released from the secondary treatment of superphosphates such as in the combined ammoniating and granulation operation.

While the particulate losses may result in visible plumes and settleable dusts, the principal air pollution problem associated with the phosphate fertilizer industry is that related to the evolution of gaseous fluorine compounds during the acidulation of phosphate rock. As will be described in more detail later, fluorine compounds are also present in most phosphate bearing mineral formations used commercially. The gaseous compounds thought to be most predominant in the reaction products of the acidulation process are hydrogen fluoride (HF) and silicon tetrafluoride (SiF_4).

These gaseous fluoride compounds damage citrus, gladioli and truck crops, and can deposit fluorine compounds on cattle forage.(2) Should cattle ingest excessive quantities of fluorides from this feed source, they may develop tooth mottling and decay (fluorosis), skeletal defects such as lameness (exotosis), loss of appatite and emaciation.

Gaseous sulfur oxides and nitrogen oxides may also be lost from phosphate fertilizer processes particularly during the use of sulfuric and nitric acids where there is a significant organic content to the material being treated. Ammonia and ammonium chloride may also be evolved during the ammoniation of phosphate fertilizers.(3)

2. Ammonium Nitrate

The possible air contaminants arising from the manufacture of ammonium nitrate from the reaction between ammonia and nitric acid are: ammonia, nitric oxide, and ammonium nitrate fume and dust. The principle problem has been the objectionable haze formed as the result of water condensing on finely divided ammonium nitrate fume lost during prilling operations (production of pellets by counter-current flow of air against falling spray of molten ammonium nitrate).

Payne and Glikin(4) state that at relative humidities above 60% at a temperature of 30°C water will condense on ammonium nitrate nuclei, causing a growth in particle size so as to result in a visible haze. Scorer(5) has also evaluated the environmental impact of a proposed British ammonium nitrate plant and predicted a fallout rate of 400 tons/mi^2/mo within 2/3 mile of the prilling operation.

B. PRODUCTS DESCRIPTION

1. Phosphate Fertilizers

The various types of phosphate fertilizers are produced commercially from mineral deposits of phosphate rock. Although major deposits are found at numerous locations throughout the world a significant proportion of commercially recoverable rock is found in the United States. At the present time the world's center of phosphate production lies in 500 mi^2 area of central Florida.(2, 3) The deposits are of the sedimentary pebble type and largely consist of phosphate in the form of fluorapatite--3 $[Ca_3(PO_4)_2] \cdot CaF_2$. This form of phosphate is rather insoluble, thus accounting for the stability of the deposits.

Commercial deposits of phosphate rock are also found in Tennessee, North Carolina, Idaho, Montana, Wyoming and Utah.(6) These deposits are also of the sedimentary type, but vary in depth, phosphorous assay, and amount of organic content.

Phosphate rock is usually mined using open strip-mining techniques, with the rock being sluiced into pipes carrying the rock slurry to beneficiation plants. Here the ore is upgraded by separating undesired sand, clay and other non-phosphate minerals by a variety of physical and flotation processes. Up to this point, the air pollution problems are minor in nature.

The beneficiated rock must be dried and pulverized before further treatment. These operations may result in major atmospheric losses of dust unless adequate controls are used. In some cases calcination is used to reduce the content of organic matter.(1) This applies to deposits largely outside of the Florida region.

Phosphate in the form of fluorapatite is very insoluble, thus reducing its availability to the soil if used directly. The success of the phosphate fertilizer industry depended upon the development of technology to produce a form of readily available phosphate. That process which has been longest in use is that which involves the acidulation of phosphate rock (fluorapatite) with sulfuric acid to produce normal superphosphate (acid phosphate). This process in one form or another has been in use for over a century. The simplified reaction involved is shown below:

$$3[Ca_3(PO_4)_2] \cdot CaF_2 + 7H_2SO_4 \rightarrow 3[Ca(H_2PO_4)_2] + 7CaSO_4 + 2HF$$

The hydrogen fluoride evolved may react with silica present to form silicon tetrafluoride:

$$4HF + SiO_2 \rightarrow SiF_4 + 2H_2O$$

Fluosilicic acid may also be formed as a result of reactions with water:

$$3SiF_4 + 4H_2O \rightarrow 2H_2SiF_6 + Si(OH)_4$$

A great deal has been written about these reactions and there is not total agreement about them or the order in which they occur.(1, 3) However, it is a fact that gaseous fluorine compounds are emitted as a result of the acidulation process, thus giving rise to a significant air pollution problem. Figure 7.14.1 shows a simplified flow sheet for the production of normal superphosphate.

Depending upon the specific process, the reactions in the acidulation step do not take place immediately, but are completed in the curing operation which may take a number of weeks or months. During the curing operation, fluorine compounds continue to be evolved and in the past have not been usually controlled. In fact, in a study conducted by Cross and Ross(7), fluoride emissions were shown to arise in significant quantities from gypsum settling ponds.

Under the stimulus of the demand for more concentrated forms of fertilizer, a process for the acidulation of phosphate rock with phosphoric acid was developed. This process results in a product known as triple

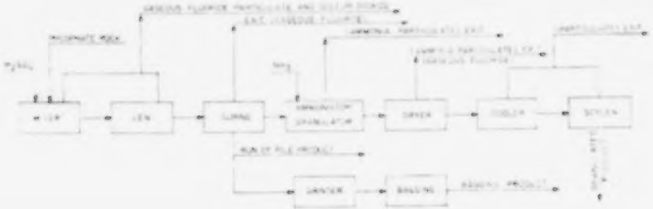
PHOSPHATE ROCK
H_2SO_4
MIXER
DEN
CURING
NH_3
AMMONIATOR GRANULATOR
DRYER
COOLER
SCREEN
RUN OF PILE PRODUCT
GRINDER
BAGGING
BAGGED PRODUCT

Figure 7.14.1 PRODUCTION OF NORMAL SUPERPHOSPHATE
(SOURCE: HELLER, et al., Reference 6)

superphosphate. The assay for available phosphorous is about 2-1/2 times that of normal superphosphate because the active ingredient is not admixed with calcium sulfate. This process is shown in Figure 7.14.2. Many of the air pollution problems in the manufacture of triple superphosphate are very similar to those of normal superphosphate production, including the evolution of gaseous fluorides.

Although not discussed in this chapter the integrated production of sulfuric acid and phosphoric acid (particularly by the wet process) are unalterably bound up with the phosphate fertilizer industry. Sulfuric acid manufacturing is, however, discussed in Section VII and the wet process for the production of phosphoric acid essentially involves the more complete acidulation of phosphate rock with sulfuric acid with the accompanying filtration of calcium sulfate from the phosphoric acid formed.

A variety of product mixes are prepared following the actual production of superphosphate or triple superphosphate. In many cases the superphosphate is sold as "run of the pile" (as it will not attempt to meet a guaranteed assay) or is ground and bogged to specifications. Increasingly, however, granulated product is produced which sometimes has been ammoniated or had other forms of nitrogen, such as urea, added. The granulation processes involve the use of other mixing and drying steps thus increasing the opportunity for dust and fume production. On the other hand, if combined ammoniation is used, the acidulation reaction is terminated and gaseous fluoride emissions are not evolved after the acidulation process itself. On the other hand, ammonia and ammonium chloride may be lost from the ammoniation process.

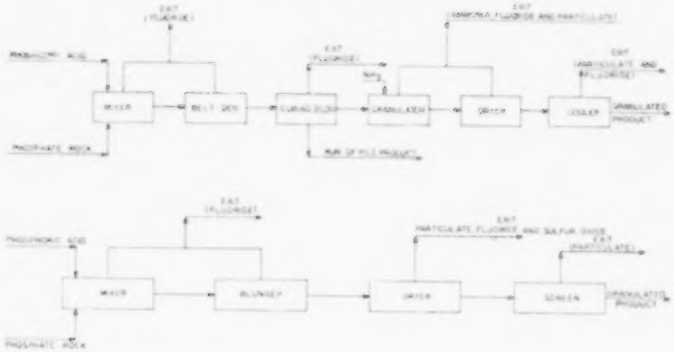
EXIT
(FLUORIDE)
PHOSPHORIC ACID
PHOSPHATE ROCK
MIXER
BELT DEN
EXIT
(FLUORIDE)
CURING BLDG
RUN OF PILE PRODUCT
NH_3
GRANULATOR
EXIT
(AMMONIA, FLUORIDE AND PARTICULATE)
DRYER
EXIT
(PARTICULATE AND FLUORIDE)
COOLER
GRANULATED PRODUCT
EXIT
(FLUORIDE)
PHOSPHORIC ACID
PHOSPHATE ROCK
MIXER
BLUNGER
EXIT
PARTICULATE, FLUORIDE AND SULFUR OXIDE
DRYER
EXIT
(PARTICULATE)
SCREEN
GRANULATED PRODUCT

Figure 7.14.2 PHOSPHORIC ACID ACIDULATION PROCESS
(SOURCE: HELLER, et al., Reference 6)

2. Ammonium Nitrate

This important source of nitrogen in fertilizer is produced by the reaction between ammonia and nitric acid to form ammonium nitrate in solution:

$$NH_3 + HNO_3 \rightarrow NH_4NO_3$$

After concentration of this solution by heating and evaporation, solid ammonium nitrate is produced by "prilling," or vacuum crystallization. Another process known as the Stengel process mixes preheated ammonia and nitric acid in a packed reactor where the heat of reaction is sufficient to vaporize the water in nitric acid feed, thus directly producing molten ammonium nitrate which is separated from the unreacted materials and water vapor by a centrifugal separator. This molten nitrate is ultimately distributed on an endless stainless steel water cooled belt where it solidifies. Vapors from the separator are recovered by condensation and scrubbing.

The "prilling" process is the more common in the United States and is shown in Figure 7.14.3. As mentioned earlier, the prilling process involves the spraying of concentrated ammonium nitrate solution down through the top of a tower through a rising stream of air. The droplets solidify and harden during their fall resulting in spherical pellets called prills which may be bagged after drying futher on a conveyor to less than 0.5% moisture. Product in this form may be kept in moisture proof bags for more than a year without caking.

The loss of fines in this process is very low but some ammonium nitrate fume may be discharged. If ammonia is added in excess, the possibility of nitric oxide loss is nearly eliminated and the ammonia may be recovered by scrubbing.

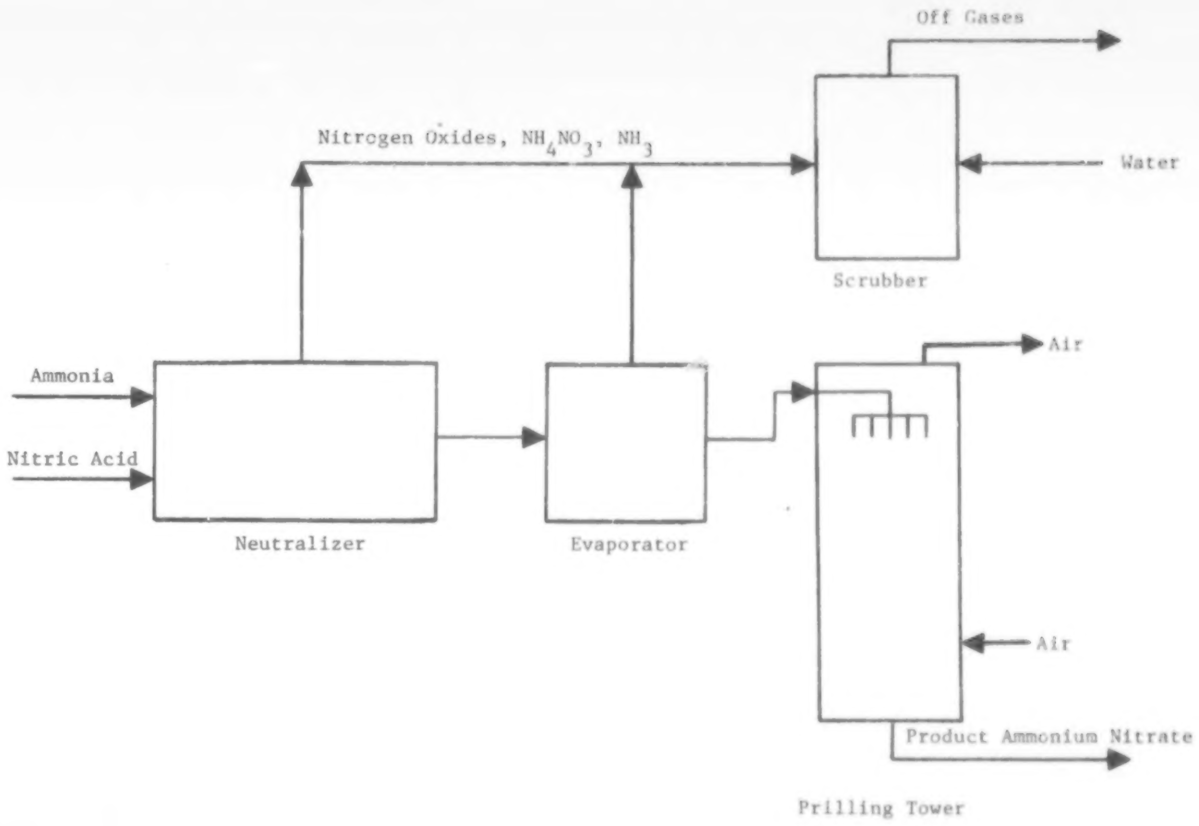
Off Gases
Nitrogen Oxides, NH_4NO_3, NH_3
Water
Scrubber
Air
Ammonia
Nitric Acid
Neutralizer
Evaporator
Air
Product Ammonium Nitrate
Prilling Tower

Figure 7.14.3 FLOW DIAGRAM FOR THE MANUFACTURE OF AMMONIUM NITRATE

The damages of fire or explosion can exist with ammonium nitrate so that great care must be taken in bulk handling. One approach has been the use of urea as an admixture to inhibit oxidation of ammonium nitrate.(4) Urea has been increasingly utilized by itself or as ureaforms as a fertilizer substance. Ureaforms are reaction products of urea and formaldehyde which release nitrogen very slowly.

3. Control Methods

The control of emissions from chemical fertilizer production basically involves the control of soluble gases, principally fluorine compounds, and finely divided particulate matter. Fluorine compounds are usually removed by water scrubbers which have been stated to range in efficiency from 92-97%. This scrubber water may go to waste or be reclaimed for value of the fluorine contained. This latter approach is increasingly being used.(8)

Particulate matter may be recovered by cyclones, cloth filters and high efficiency scrubbers. Because of great numbers of possible emission points from both phosphate and ammonium nitrate production, Table 7.14.1 has been prepared which lists emission sources, types of emissions, and possible means of control.

In general, a number of principles should be applied when considering control approaches for fertilizer plants. For the proper control of dusts, all conveyors, feeders, hoppers, bins, and size reduction equipment should be closed and properly vented to the dust abatement equipment. Adequate ventilation velocities should be based upon accurate knowledge of the particulate size distribution involved.

Gaseous fluoride emissions should be collected properly and a determination made of all possible emission points. Where curing operations are

Table 7.14.1 CONTROL OF EMISSIONS FROM FERTILIZER MANUFACTURING

Source	Nature of Emissions	Control Method(s)
Phosphate Fertilizers		
Rock Drying	Rock Dust	Cyclones and Wet Scrubber
Rock Crushing and Grinding	Rock Dust	Baghouses
Acidulation	HF, SiF_4	Water Scrubber
Curing (denning)	HF, SiF_4	Water Scrubber
Granulation	Product Dust	Cyclones and Wet Scrubbers or Cloth Filters
Ammoniation	NH_3NH_4Cl, SiF_4, HF	Cyclone, Elect. Precip., Cloth Filters, Highest Scrubber
Nitric Acid Acidulation	NO_x, Gaseous F Cpds.	Scrubbers, Addition of Urea
Superphosphate Storage and Shipping	Product Dust	Cyclones, Cloth Filters
Ammonium Nitrate		
Reactor	NH_3, NO_x	Scrubbers
Prilling Tower	NH_4NO_3 Fume	Reduce Formation by Control of Conditions

used, they should be conducted inside enclosures through which air can be recirculated and passed through a scrubber. Consideration should be given to the reduction of losses from gypsum ponds.

C. INSPECTION POINTS

1. General

The chemical fertilizer industry has been shown to be a variety of separate industries ranging greatly in complexity, types of operations, and nature of potential environmental impact. A "fertilizer plant" may range from one engaged in the relatively simple process of blending and packaging bulk dry ingredients to a large scale integrated operation involved in mining raw materials; crushing, grinding, and drying these materials; conduct of chemical processing; and finally blending and packaging of finished product.

Because of the seasonal demand for fertilizer, plant operation often follows a similar cyclic pattern with maximum production just prior to peak demand. Nearly every type of air pollution control equipment may be found in use in the fertilizer industry, ranging from inertial collectors through fabric filters, water scrubbers and electric precipitators.

The factors listed above require a varied approach to the overall field inspection and abatement operations. In relatively simple cases, straightforward inspection procedures involving primarily an inspection of the source premises may be adequate. In the case of very large integrated plants where there are potential toxic emissions a team approach may be desirable. In addition to the regular field abatement personnel specialists in chemistry, process and control engineers, meteorologists, and plant and animal scientists may be called upon.

2. Environmental Surveillance

The most significant efforts in environmental surveillance will be concerned with the phosphate fertilizer industry as a result of the potential for the emission of gaseous fluoride compounds and in some cases sulfur dioxide, hydrogen sulfide, and nitrogen oxides. Other candidates for special surveillance activities would include the evaluation of the deposition of particulates from many of the fertilizer processes, and plume formation from ammonium nitrate plants.

In the case of fluoride emissions from phosphate fertilizer production two types of surveillance activities may be employed. The first involves the determination of possible damage to susceptible receptors, i.e., citrus, row crops, ornamentals and grazing animals (through fluorides deposited on forage). This type of activity will require extensive training of field personnel and the cooperation of land users sustaining damage at the minimum. Desirably, other resource individuals such as farm advisors, veterinarians, and university personnel will be utilized as well. Techniques such as this have been described by Hendrickson.(2)

Environmental surveillance may also be conducted by sampling for suspected emissions in the ambient atmosphere. Most surveys for atmospheric fluorides have been conducted by the use of static sampling utilizing lime or calcium formate impregnated papers, but continuous analyzers have been used as well.(2, 7)

3. Plant Inspection

a. Interview

As in the case of any complex pollution source, the interview of plant management should include the obtaining or verification of process descriptions, flow sheets, equipment lists and management's estimate of emission inventories. Information on process variations and production scheduling should be obtained. Should source test data be available it should be secured and examined. Statements from plant management on plant operations, their assessment of pollution problems and plans for control should be requested.

b. Physical Inspection

The inspector should obtain and/or verify the plant layout and equipment location. He should observe each process step. Several visits may be necessary before a representative set of operating conditions, production rates and meteorological conditions have been covered. In the case where much process and control equipment is used in the fertilizer industry, corrosion, erosion and other forms of mechanical wear and tear are a major problem. It will be important, therefore, to make careful observations as to the condition and maintenance level for important items of equipment.

Another significant factor in terms of overall emission rates from a plant, process or operation is the effectiveness of emission pickup and retention in the exhaust and control system. This is especially important to examine in the fertilizer industry where so much bulk transfer of material in particulate or granulated form takes place.

The inspector should determine what design factors are used for control equipment such as volumetric flow rates, entrance velocities to centrifugal collectors, water flow rates for scrubbers, pressure drop across scrubbers, etc. Adherence to design rates should be evaluated. Secondary sources of pollution such as waste water treatment facilities, settling ponds and fluoride recovery systems should be examined.

An increasing use of process control instrumentation in the fertilizer industry provides another potential source of information useful to inspection personnel. Of particular importance would be any instrumentation used to control feed rates and that used to monitor effluents.

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XV. PAINT AND VARNISH MANUFACTURING

A. NATURE OF SOURCE PROBLEM

The paint and varnish manufacturing industry in a fairly broad context could be said to include synthetic resin manufacturing, varnish cooking, and paint blending processes. Of these, the first two present the greatest air pollution control problems.

The major air pollutants from synthetic resin manufacturing would include emissions of monomers and other raw materials from storage and reaction vessels, sublimed phthalic anhydride and oil bodying odors from alkyd resin manufacturing, and possible solvent losses during thinning operations and storage of thinned resins.

Varnish cooking presents the greater of the air pollution problems in this industry because of the wide variety of odorous substances released during the polymerization and other chemical reactions that the natural drying oils enter into during the cooking process. These range from acrolein and other partially oxidized organic compounds to sulfur derivatives, some of which are detectable in the parts per billion range. Some varnish cooking is still carried out in open vessels which complicates the design and operation of control equipment.

Solvent losses may also occur in the thinning of varnish and in paint blending operations.

B. PROCESS DESCRIPTION

Two of the principal ingredients in protective coatings are resins and drying oils. When organic solvents and driers (soaps of heavy metals) are added to the heat processed blend of the resin and oil the product is known as varnish. The addition of pigments to varnish results in enamel type paints. The manufacture of water-based paints bears little relationship to oil-based paints and varnishes from an air pollution point of view and will not be considered here. The resins used in water-based paints are usually produced in chemical process plants using continuous processes.

Resins used in varnish production may be either natural or synthetic. Natural resins include Rosin, Congo, Batu, Dammar and Lac. These natural resins in dry form are added at some point during the heat processing of natural drying oils known as varnish cooking. Oleoresinous (oil plus resin) varnishes result. This process will be described later in this section.

A number of synthetic resins are also used in the preparation of protective surface coatings. A partial list would include modified phenolic, alkyd, coal tar, urethane and petroleum-based resins. Most of these are produced in closed reaction vessels and are more properly considered under the chemical process industries. However, the alkyd resins are sufficiently different and are in such widespread use as to justify a description of the manufacturing process.

1. Alkyd Resin Manufacturing

Alkyd resins are a special class of polyesters modified by additions of fatty, monobasic acids. As a general class a polyester resin is defined as the product of a condensation reaction between a polyhydric alcohol and a polybasic acid. Thus, an alkyd resin might contain as base ingredients phthalic anhydride, glycerol and a fatty acid formed from a natural oil such as linseed.

Other natural oils used as modifiers include cottonseed, soya, tung, and sometimes, fish oil. Other base ingredients used include maleic and formic acids, and alcohols such as ethylene glycol, mannitol, pentaerythritol and sorbitol.

The production of alkyd resins is usually carried out in an enclosed, indirectly heated reaction vessel equipped with a stirring mechanism, a condenser, and usually a scrubber. All ingredients may be cooked simultaneously, or the oil and a portion of the alcohol component (such as glycerol) may be added first to convert the naturally occurring triglycerides in the oil to a more reactive monoglyceride form. The resin is formed by reacting this monoglyceride with the acid (such as phthalic anhydride) at a temperature slightly below 500°F, using agitation and sparging with inert gas. The reaction is carried out until the desired viscosity is attained.

Because of the use of natural drying oils as modifiers, a variety of odorous, noncondensible gases are given off during alkyd resin manufacturing which are similar to those emitted from the production of oleoresinous varnishes. These include acrolein, other aldehydes, fatty acids, etc. This class of air contaminants is generally controlled by fume burners. Addition of phthalic anhydride to the heated drying oils may cause the emission of visible plumes of the sublimed anhydride.

2. Varnish Cooking

Varnish cooking generally refers to the manufacture of oleoresinous varnishes. Four groups of materials are used in preparation of the final form used for protective or decorative coating. These include antioxidants, resins, drying oils, driers, and solvents. While there is a good deal of variety in all four groups, an almost endless number of resins and drying oils are used. To a considerable extent the nature of these materials influences the possible air pollution problem.

The principal reactions taking place in the manufacture of varnish involve the addition of heat. Reactions include:

a. Polymerization of the drying oils. Some, such as tung oil, are easily polymerized and are added early in the processing while with a slower bodying (polymerizing) oil such as linseed oil a certain amount of prebodying may be carried out before the resin is added.[1]

b. Depolymerization. Certain natural fossil resins are of such high molecular weight that heat-assisted cracking (depolymerization) is necessary before the resin is ready soluble in the oil.

c. Melting and solution.

d. Esterification. Natural rosin or tall is modified for use in some varnishes by esterification with a polyhydic alcohol such as glycerol or pentaerythritol. The product, ester gum, is almost always used in conjunction with other resins.

e. Gas checking. Certain of the faster reacting conjugated oils, such as Chinawood oil, tend to form crystalline films giving a frosted or "gas checked" effect. This effect can usually be prevented by heating to top temperatures of 575-585°F during the cooking.

f. Distillation and Evaporation. Used to remove volatile constituents, particularly such as those present or formed during esterification of tall oil or rosin.

The air pollution problem in oleoresinous varnish cooking largely is a result of the breakdown products of resin depolymerization, the thermal decomposition and oxidation products of oil bodying, the volatile portion of the raw materials, and the by-products of gum running (esterification). These might include fatty acids, formic acids, acetic acid, glycerine, acrolein, other aldehydes, phenols, and terpenes.(1) In the case of tall oil esterification, hydrogen sulfide, alkyl sulfide, butyl mercaptan, and thiophene may also be emitted. These sulfur compounds are present in unpurified tall oil as a result of the sulfides used in the kraft wood pulping process from which the tall oil by-product is produced.

A significant amount of solvent may be lost to the atmosphere if added to hot cooked varnishes where proper solvent recovery equipment or controls are not used. This is most likely when the solvent cut-back or thinning operation takes place in open varnish kettles.

The type of vessel used for varnish cooking can have a significant effect on the air pollution problem. The old, open movable kettle (Figure 7.15.1) having a capacity ranging from about 150 to 500 gallons is heated over a fire pit making close temperature control somewhat difficult.(2) Because odorous fume evolution is temperature dependent, excessive temperatures or local hot spots can increase fume loss and even change the nature of the effluent. Further, the installation of a close fitting effective fume hood and at the same time allowing the flexibility necessary for use over a movable kettle is more difficult than hooding a fixed fume source.

Much of the varnish cooking is now carried out by chemical companies and large paint plants in closed reactor kettles having an external source of heat supplied by a heat transfer medium such as Dowtherm.(3) Some are directly heated with gas, oil or electric resistance heaters. Internal cooling coils may also be provided. Temperature can be controlled much more closely than in open kettles. Liquid raw materials are pumped with solids being added through a sealable port. These closed systems are often equipped with vapor recovery condensers. The

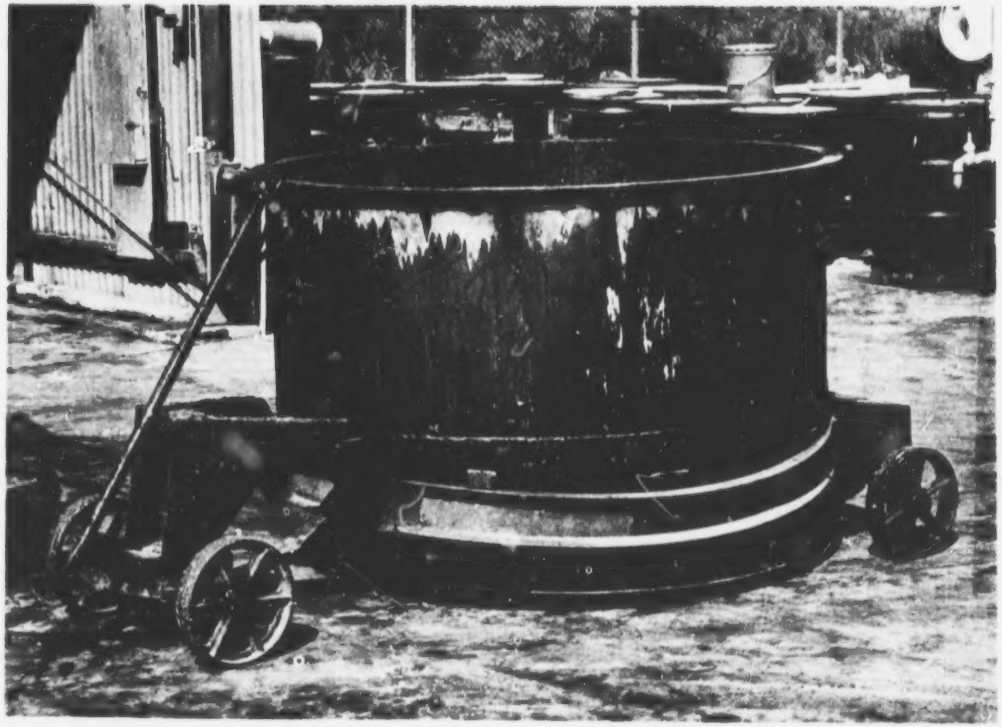


Figure 7.15.1. UNCONTROLLED OPEN KETTLE FOR VARNISH COOKING (SOURCE: AIR POLLUTION ENGINEERING MANUAL, Reference 4)

product is withdrawn by pumping and is transferred to solvent thinning tanks usually equipped with agitators and integral reflux condensers to reduce solvent losses.

Solvent loss control has become of more concern since the adoption of regulations such as Rule 66 of the Los Angeles County Air Pollution Control District and Regulation 3 of the Bay Area Air Pollution Control District (California). From the standpoint of total volume and photochemical air pollution potential, the control of certain types of solvents such as olefins, branched chain aromatics and ketones may be of more importance in the general air pollution picture than is the control of varnish cooking fumes. However, the localized nuisance and visible plume aspect of varnish cooking fumes cannot be neglected.

3. Air Pollution Control Techniques

The application of the best technology in the paint and varnish industry would call for the use of fume burners wherever varnishes are cooked or drying oils are heat processed. In some cases pre-collection devices such as water scrubbers for the control of phthalic anhydride fumes are in order. Generally speaking, other means of control such as activated carbon adsorption units are not satisfactory for use with odorous fumes containing tacky particulate matter such as is contained in typical varnish cooking fume.

Solvents may be controlled by use of closed thinning vessels, temperature control, condensers, and in some cases, fume burners.

Fume or afterburners should be designed to accomplish three objectives: (1) eliminate visible plumes, (2) eliminate odor, and (3) oxidize all organic substances to carbon dioxide and water.

These objectives can only be met by good mixing of the plume in the combustion zone, application of sufficient heat to reach some acceptable minimum temperature, and provision of sufficient residence time at these conditions to permit quantitative oxidation of the organic material in the fume.(4) Both direct flame and catalytic afterburners have been applied to varnish cooking operations.

In general, sufficient auxiliary fuel (usually gas) must be supplied in direct flame afterburners to heat the exhaust air containing the process effluent to a range of 1200°-1500°F. Maximum flame contact time is desirable. A minimum residence time of the effluent stream in the combustion zone of 0.3-0.5 seconds is suggested,(4) although longer times may be desirable in cases of materials resistant to oxidation.(5) Good mixing can be achieved by proper combustion chamber design. One type of fume burner design which has often been used successfully involves the use of tangentially fixed burners (Figure 7.15.2). A number of other proprietary designs have been developed with the objectives of maximizing flame contact and promoting good mixing. Figure 7.15.3 is a schematic diagram of a burner in which the process effluent is forced to travel through the flame. An overall schematic view of a varnish cooking fume burner control system is shown in Figure 7.15.4.

Catalytic afterburners have also been used to control varnish cooking fumes and odors. The principle advantage of such an approach according to theory is that the use of a catalyst allows the oxidation reactions to take place at a lower temperature thus reducing the use and cost of auxiliary fuel. Mixed success has been achieved in the use of catalytic afterburners for organic emissions. Some apparently are successful while in other cases, odors not

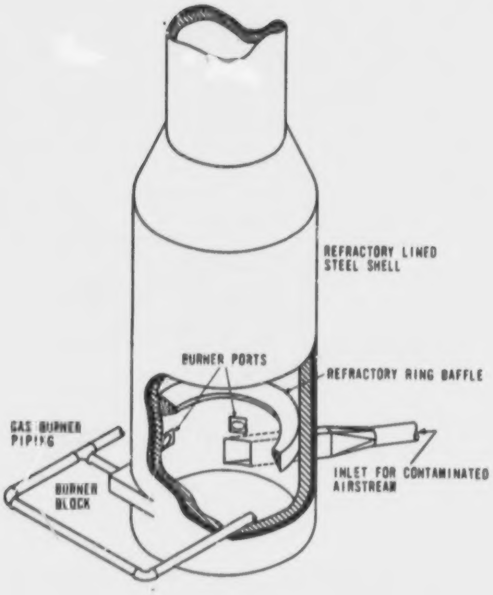

REFRACTORY LINED
STEEL SHELL
BURNER PORTS
REFRACTORY RING BAFFLE
GAS BURNER
PIPING
INLET FOR CONTAMINATED
AIRSTREAM
BURNER
BLOCK

Figure 7.15.2. TYPICAL DIRECT-FIRED AFTERBURNER WITH TANGENTIAL ENTRIES FOR BOTH THE FUEL AND CONTAMINATED GASES. (SOURCE: AIR POLLUTION ENGINEERING MANUAL, Reference 4)

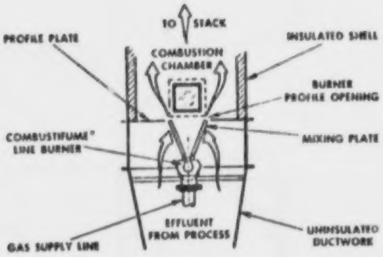

TO STACK
PROFILE PLATE
INSULATED SHELL
COMBUSTION CHAMBER
BURNER PROFILE OPENING
COMBUSTIFUME® LINE BURNER
MIXING PLATE
EFFLUENT FROM PROCESS
GAS SUPPLY LINE
UNINSULATED DUCTWORK

Figure 7.15.3. DIAGRAM OF COMBUSTIFUME BURNER IN VERTICAL STACK (SOURCE: JOURNAL OF THE AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, Reference 5)

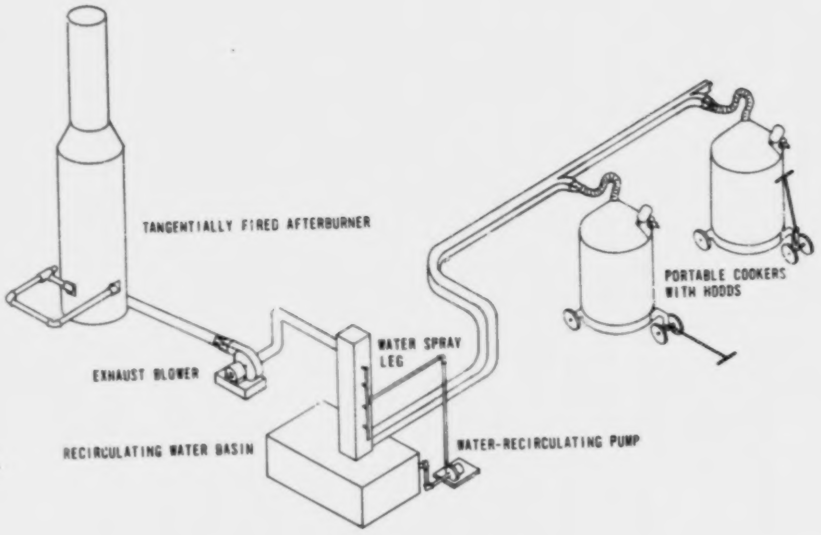

TANGENTIALLY FIRED AFTERBURNER
PORTABLE COOKERS WITH HOODS
WATER SPRAY LEG
EXHAUST BLOWER
RECIRCULATING WATER BASIN
WATER-RECIRCULATING PUMP

Figure 7.15.4. SCHEMATIC PLAN FOR VARNISH-COOKING CONTROL SYSTEM (SOURCE: AIR POLLUTION ENGINEERING MANUAL, Reference 4)

originally present in the effluent can result. Specific test information is desirable before the performance of catalytic units can be predicted with confidence. Selheimer and Lance,(6) for example, report that a laboratory scale test of a catalytic combustion process was successful on a given varnish cooking effluent at a temperature of 700°F.

C. INSPECTION POINTS

With the exception of opacity regulations there are relatively few specific prohibitory regulations dealing with the paint and varnish industry. In most cases, prohibitions of odorous organic fumes such as those arising from uncontrolled varnish cooking are based upon nuisance law. There are a few agencies such as the San Francisco Bay Area Air Pollution Control District (Regulation 3) which have mass or concentration standards for certain organic compounds, and there is increasing interest in quantified odor measurement standards, but these are the exception at the present time. Consequently the inspector should become familiar with the conduct of an odor survey (see Chapter 6, Section VI).

Solvent losses from thinning operations in some cases may be governed by specific regulations (see Rule 66, L.A. County APCD), but this class of regulation is far from universal.

Control of solvent losses is based quite often on best technology either with or without the aid of a permit system.

The inspector will have several main tasks in relationship to the inspection of paint and varnish related industries. These would include:

- General surveillance for odors and possible visible plumes
- Investigation of odor complaints.

- Determination of nature of processes carried out, including the range of materials processed.

- Inspection of production and control equipment and the determination of operating practices.

- Determining whether source testing is desirable.

1. Environmental Observations

The major obvious environmental effects which can possibly be observed would include the broad spectrum of odors possible from varnish cooking and alkyd resin manufacturing, odors from aromatic and unsaturated solvents such as dicyclopentadiene, surface contamination from oil mists, and visible plumes from cooking operations or from the uncontrolled emission of phthalic anhydride.

Odors originating from varnish cooking operations are quite varied depending upon the raw materials and stage of the process. Some are characteristic of vegetable drying oils such as linseed, oiticica, and castor oils. Fish oils would be easily recognized by their characteristic odor. Other pungent and sometimes irritating odors are formed by the partial oxidation and polymerization reactions taking place during the cooking process. Terpene or pine oil odors together with sulfur compound odors could possibly originate from the use of tall oil. Most of these odors are rather pervasive and ill smelling. Some are slightly nauseous in higher concentrations.

The inspector must be careful to note wind speed and direction, relative humidity, atmospheric stability and other possible odor sources when tracking odors or investigating odor complaints. Tracking of odors should be done systematically noting times, locations, and odor type and intensity during the investigation. Should regular complaint patterns develop, a community odor panel may be utilized to obtain more objective evidence on time, location, quality and intensity of odors.

Plume sources should be carefully identified and observations should be made consistent with good opacity observation practices (see Chapter 5). Complaints of damage from oil droplets should be plotted on a map and identification of materials made by collecting samples of glass plates for laboratory examination in case of materials of doubtful origin.

2. Observations of Plant Exterior

Points of emission visible from the exterior of paint and varnish plants are process vent stacks serving resin kettles and varnish cooking operations, condenser vents from storage of heated liquid phthalic anhydride and solvent thinning tank vents. Visible plumes may or may not be associated with varnish cooking operations. In general there should be no readily visible plume from a varnish cooking operation served by a fume burner.

Intermittent visible emissions may result from the addition of resins to hot oils and from thinning operations when the cooked varnish has not been cooled sufficiently. Visible emissions may also result from filling operations in liquified phthalic anhydride storage tanks.

3. Interior Plant Inspection

a. The Interview

The interview with plant management should be directed towards obtaining information about the process operations as they affect the air pollution potential, to determine operating and maintenance procedures, and to examine applicable records such as fume burner temperature recorder charts (if used). Examples of specific types of information to be obtained by interview are:

- Nature of raw materials used and finished product manufactured. It is particularly important to determine the type of natural drying oils used in varnish cooking or in modifying alkyd resins as the odor potential may be quite different for each. A list of solvents used should also be obtained.

- Process descriptions should be obtained such as sequence of materials added to cooking vessels, temperatures used, length of cook, technique used for solvent thinning operations, and equipment used for various operations.

- Operation and maintenance schedules should be determined particularly as to time of day that varnish cooking operations are carried out. Maintenance of exhaust systems serving varnish cooking operations is important because of the great potential for lines being partially obstructed with fume deposits. Obstructed lines may reduce exhaust flow rates and thus result in less effective fume pickup at hoods over open varnish cooking kettles.

- Production data is important in determining emission inventory data by the application of general or specific emission factors.

- Exhaust and control system data.[5] Plant management should be asked to provide data on exhaust flow rates used, amount of fuel used in afterburners, water rates in any water scrubbers used, and on any internal guidelines or procedures used to determine the effectiveness of the control equipment.

b. The Physical Inspection

The physical inspection should concentrate on equipment which is a potential source of air contaminants or designed to control them. It is important that some inspections be made during the conduct of operations having the greatest air pollution potential. Safety procedures instituted by plant management particularly near hot and flammable materials should be respected. Important items to observe are:

- Specific equipment used for each relevant operation, where and how used.

- Condition of fume exhaust equipment including fans, drive belts, hooding, ducts and control equipment. Examination should be made for leaks, clogged ducts and general level of maintenance.

- Functioning of exhaust and control equipment including hooding effectiveness, hood in-draft velocities, evidence of fume burner fuel-use rates, afterburner temperatures and relationship of these parameters to evidence of visible plumes and odors.

- Data obtained in the interview should be verified wherever possible during the inspection. This is particularly important with respect to operational procedures.

REFERENCES

1. Maltiello, J. J. (ed.). Protective and Decorative Coatings, Vol. III. New York, John Wiley and Sons, Inc., 1943.

2. Maltiello, J. J. (ed.). Protective and Decorative Coatings, Vol. I. New York, John Wiley and Sons, Inc., 1941.

3. Payne, H. F. Organic Coating Techmology, Vol. I. New York, John Wiley and Sons, Inc., 1954.

4. Danielson, J. A. (ed.). Air Pollution Engineering Manual. Cincinnati, DHEW, PHS, National Center for Air Pollution Control and the Los Angeles County Air Pollution Control District. P.H.S. No. 999-AP-40, 1967.

5. Waid, D. E. Incineration of Organic Materials by Direct Gas Flame for Air Pollution Control. Am. Ind. Hyg. Assoc. J 30, 291-297. 1969.

6. Selheimer, E. W., and R. Lance. Analysis of Fumes Leaving Resin Kettles and Fume Abatement Equipment. Off. Dig. Fed. Paint and Varnish Prod. Clubs, 27, 711-68. August, 1954.

XVI. GALVANIZING OPERATIONS(1)

A. DESCRIPTION OF SOURCE

The coating of iron and steel materials (sheet metal, structural shapes and wire) with zinc to prevent oxidation is an industrial practice commonly found in most industrialized communities. The primary source of air contaminants is the galvanizing kettle containing molten zinc.

Galvanizing operations can be conducted on a batch basis, as in the coating of nuts and bolts, or as a continuously fed operation as in the coating of wire or chain link fencing. This process may be found in job shops or as a captive operation in a large plant.

B. PROCESS DESCRIPTION

Since the surface of the material to be coated must be free of rust and oil so that the zinc can adhere to it, the product must go through cleaning and degreasing processes prior to the hot zinc dip. The cleaning process has air pollution control impact as well as a quality control consideration. If the metal to be coated is not clean, oil mists can be generated and an increased use of flux for proper coating action will be required with resultant increases in fume emissions.

The process flow shown in Figure 7.16.1 is usually independent of batch or continuous operations. Variations occur in the physical design of the galvanizing kettle and its ventilation system, depending upon whether batch or continuous operations are employed. For example, galvanizing chain link fencing will require kettle configurations which differ substantially from kettles used for structural shapes and fasteners.

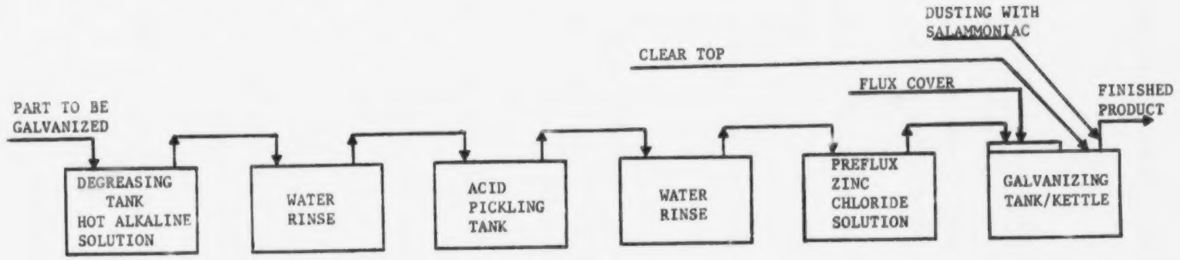

PART TO BE GALVANIZED
DEGREASING TANK HOT ALKALINE SOLUTION
WATER RINSE
ACID PICKLING TANK
WATER RINSE
PREFLUX ZINC CHLORIDE SOLUTION
GALVANIZING TANK/KETTLE
CLEAR TOP
FLUX COVER
DUSTING WITH SALAMMONIAC
FINISHED PRODUCT

Figure 7.16.1. SIMPLIFIED FLOW CHART OF GALVANIZING PROCESS

In the galvanizing step, zinc is maintained in the molten state at a maximum temperature of 860°F. The kettle is heated externally so that the products of combustion do not enter the process and are separately vented. A flux cover is maintained on the surface of the molten metal bath primarily to remove oxide formations from the metal to be coated (some small amount of oxide may be formed between cleaning and the hot dip) and to exclude air from the part as it enters the zinc bath. The secondary functions of the flux cover are to reduce heat losses from the bath, reduce spattering of molten zinc and to keep the molten zinc surface free of oxides thus assuring a bright coating on the product.

While a flux cover is necessary in the galvanizing process it is also the major cause of the emission of air contaminants. The two fluxes in common use are ammonium chloride and zinc ammonium chloride plus a foaming agent such as glycerine, wood flour or sawdust to provide a deeper flux layer and to extend the life of the flux. Visible emissions occur when this cover is disturbed by piercing it with the product to be coated, adding new flux, or in dusting the product with ammonium chloride as it is removed from the bath to assure an even flow of zinc on the plated surface. Emissions are usually grey with the opacity varying according to the mechanical agitation of the flux cover resulting from any of the above conditions and especially from dusting when nearly all of the flux is converted to dense ammonium chloride fumes.

As the configuration of the galvanizing kettle varies it is necessary to vary the air pollution control system to capture the effluent caused by this process. Figure 7.16.2 shows a galvanizing batch operation. The flux may be noted on the surface of the bath in the foreground. The parts are dusted with ammonium chloride to form a bright finish. Figure 7.16.3 shows the same tank with a room type hood covering the kettle. This hooding design allows for overhead materials handling equipment to be used and gives the operators unimpaired access to the kettle.

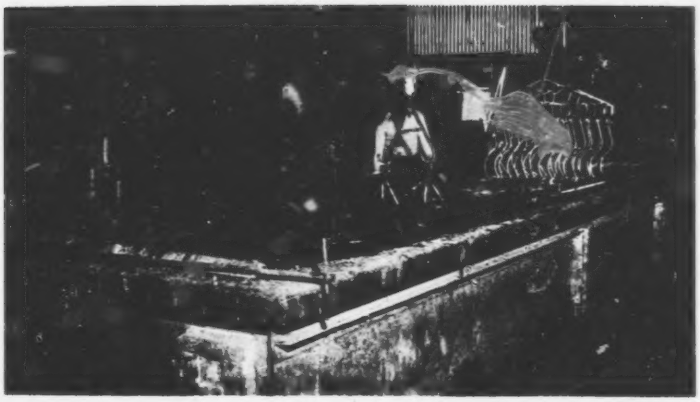


Figure 7.16.2. REMOVING WORK THROUGH A CLEAN ZINC SURFACE. FLUX COVER IN FOREGROUND, LOS ANGELES GALVANIZING CO., HUNTINGTON PARK, CA. (SOURCE: THOMAS, Reference 1)

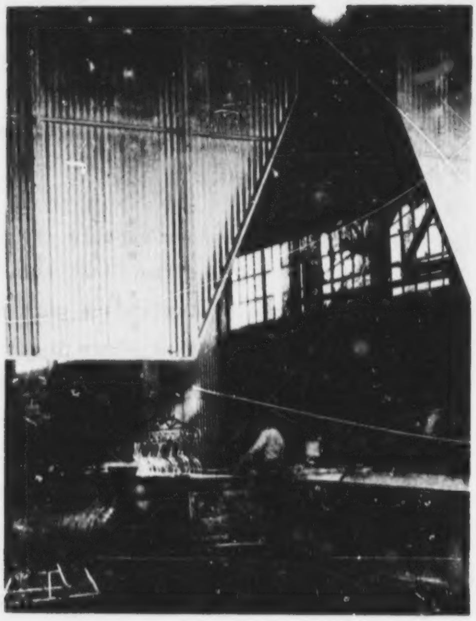


Figure 7.16.3. OPEN TO A ROOM-TYPE HOOD OVER A GALVANIZING KETTLE, LOS ANGELES GALVANIZING CO., HUNTINGTON PARK, CA. (SOURCE: THOMAS, Reference 1)

Figure 7.16.4 illustrates a slot hood (high inlet velocity) used in a continuous operation for galvanizing chain link fences. As in most open processes the design of the ventilation system is critical. Good engineering practices, outlined in Chapter III of the Air Pollution Control Engineering Manual, describe inlet velocities, materials of construction, fan requirements, and other factors of interest to the inspector.

Fume arresting equipment commonly used to capture the effluent from this process include scrubbers which produce the least satisfactory results; precipitators, where oil mists are a significant part of the air contaminants to be captured, and baghouses where there is little or no oil mist entering the exhaust system. Recent experience has shown that precipitators are more sensitive and require more maintenance than do baghouses for this application. While a baghouse requires less maintenance, the temperature inside must be kept above the dew point, even when not in use, to prevent condensation on the bags. Also consideration has been given to using a mechanical separator upstream of the baghouse to remove oil mists from the effluent in cases where oil mists present a problem.

The requirement for high efficiency air pollution control equipment in galvanizing operations is necessitated by the small particle sizes of the fumes generated. The average particle size is 2μ as illustrated in Figure 7.16.5 of a photomicrograph of fume collected from a galvanizing kettle. Table 7.16.1 shows the chemical analysis of materials collected from galvanizing kettles in a baghouse and in an electrical precipitator.

C. INSPECTION POINTS

Galvanizing operations, whether in large integrated plants or in job shops would be cited under opacity vs. time, process weight vs. allowable emissions, or public nuisance regulations. Usually in job shops there

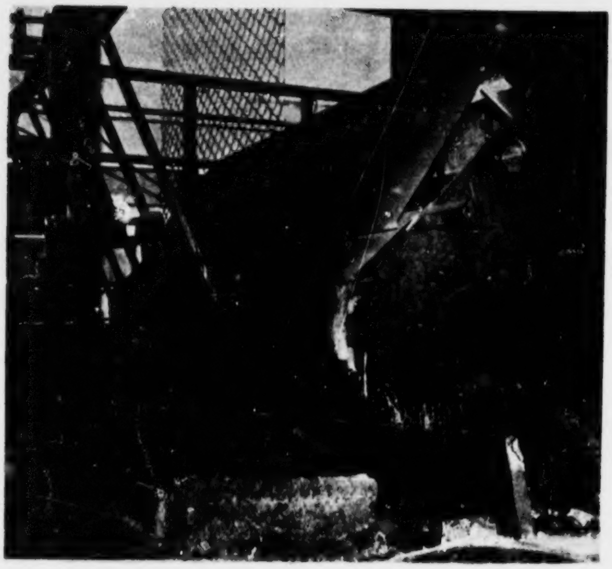


Figure 7.16.4. SLOT-TYPE HOOD SERVING A CHAIN LINK FENCE-GALVANIZING FLUX BOX, ANCHOR POST PRODUCTS, INC., OF CALIFORNIA, WHITTIER, CALIF. (SOURCE: THOMAS, Reference 1)

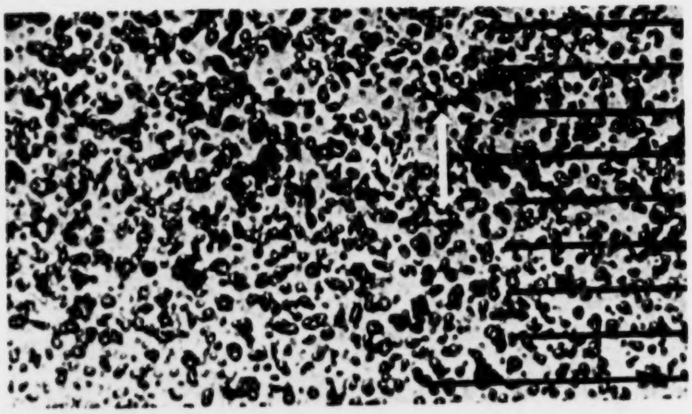


Figure 7.16.5. PHOTOMICROGRAPH OF FUMES DISCHARGED FROM A GALVANIZING KETTLE (SOURCE: THOMAS, Reference 1)

Table 7.16.1. CHEMICAL ANALYSES OF THE FUMES COLLECTED BY A BAGHOUSE AND BY AN ELECTRIC PRECIPITATOR FROM ZINC-GALVANIZING KETTLES

Component	Fumes collected in a baghouse (job shop kettle), wt %	Fumes collected in a precipitator (chain link galvanizing), wt %
NH_4Cl	68.0	23.5
ZnO	15.8	6.5
$ZnCl_2$	3.6	15.2
Zn	4.9	-
NH_3	1.0	3.0
Oil	1.4	41.4
H_2O	2.5	1.2
C	2.8	-
Not identified	-	9.2

(SOURCE: THOMAS, Reference 1)

will be a one or at most two-shift operation (7:00 a.m. to 11 p.m.) while three-shift operations are not uncommon in large integrated plants. At best, opacity readings are very difficult outside of daylight hours so it may be necessary for the inspector to determine if there is any difference in operating procedures during the various shifts.

The inspector will find it nececessary to observe the metal precleaning operations, determine the type and quantity of flux and foaming agents used, the normal hours of operation, and to isolate the location of the galvanizing kettles within the plant relative to windows and roof monitors, and the location of the air pollution control equipment serving the kettles.

1. Environmental Observation

Due to the density and opacity of possible emissions from galvanizing plants public attention can be drawn to these operations. Often nuisance complaints will arise from "dense white smoke" which can result from galvanizing operations. Complainants may be helpful in gathering information regarding excessive emissions during hours when the inspector is usually not in the area, allowing him to modify his hours of patrol to observe and record any variations in operations.

2. Observations of the Exterior of the Plant

An initial inspection of galvanizing operations may arise from the observation of dense clouds of grayish emissions from the roof monitors and windows of the building housing the operation or from the air pollution control equipment which serves the kettle. In job shops this operation will be easy to pinpoint from outside the plant but in a large industrial complex only a systematic inventory of equipment and processes may spot the location of the operation.

Uncontrolled galvanizing operations are characterized by intermittent dense clouds of fume and oil mists and continuous light grey emissions. Plants with air pollution control systems may still emit noticable quantities of fumes during dusting, as a result of adding flux or agitation of the bath, depending on the ventilation system design and its state of repair.

3. Inspection of the Interior of the Plant

Upon entering the plant the inspector should discuss with the plant operator the observations made outside of the plant, including a description of the emission and whether or not violations of any regulations were recorded. The interview may continue during the inspection and include:

a. A detailed explanation of operating procedures and any variations from these procedures that may have occurred immediately preceding the inspection.

b. The type and quantity of flux used, frequency of addition of new flux and the quantities added.

c. Description of the material to be galvanized and the normal process weight in pounds per hour. (Material to be plated, flux, and quantity of zinc added as makeup).

d. Normal operating periods, hours of the day and days of the week.

e. Any experimental work done with fluxes or foaming agents.

The observations should include:

1. At initial inspection:
    a. Overall dimensions of the tank.
    b. Sketch of the air pollution control system.
    c. Make and model number of the air pollution control equipment (if not a catalog item, details of design such as water rate for scrubbers, filter area for baghouses and fan capacity and motor horsepower should be noted).
    d. Make and model number of burners, type and quantity of fuel used. If oil is used there is a possibility of smoke emissions, especially during startup. Depending on the sulfur content of the oil, SOx emissions in excess of that allowed may occur.

2. After the initial inspection any changes to the equipment and operating procedures should be noted since permit action may be required.

3. Observe one or more operating cycles including fluxing and dusting. The inspector should determine the varieties of materials galvanized to observe the worst operating conditions.

4. Check for the condition of repair of the ventilation system and estimate fume-pickup efficiency during the periods of worst fuming.

5. Check for repair of fume suppression equipment, i.e., are there leaks, visible emissions from points other than the equipment exhaust duct; have the bags been shaken or do they appear to be clogged; is there full water pressure to the scrubber.

Any items that vary from normal operating conditions should be challenged by the inspector to determine if there has been negligence in the operation, equipment breakdown or a change in operation.

For plants that have no air pollution control systems, suppression of emissions will depend solely on the use of a flux cover. At least one hour of operation should be observed to record time and opacity of emissions.

REFERENCE

1. Thomas, G. Zinc Galvanizing Equipment. In: Air Pollution Engineering Manual, J. A. Danielson (ed.). Cincinnati, DHEW, PHS, National Center for Air Pollution Control and the Los Angeles County Air Pollution Control District. PHS No. 999-AP-40. 1967.

XVII. ROOFING PLANTS--ASPHALT SATURATORS

A. DESCRIPTION OF SOURCE(1)

Asphalt impregnated paper and felt, which is used extensively in the building trades, is manufactured by means of asphalt roofing saturators. These are high speed continuous processes using still bottoms from petroleum crude oil. The saturators are a major source of vapors, liquid particulates and steam emissions. Total emissions may range from 50 to 100% opacity where air pollution control systems are inadequate. Unless properly controlled, these operations can be a major nuisance, particularly if located within a metropolitan area.

B. PROCESS DESCRIPTION

Felt used in this process is derived from vegetable fibers and contains 5 to 10% moisture. It is continuously fed through a machine known as a saturator (Figure 7.17.1) where it is impregnated with asphalt at 400 to 450°F. The felt enters the machine through a series of dry loops (to preclude binding) where one side of the felt is sprayed with asphalt. The spray serves to drive the moisture from the felt to assure smooth coating in the saturator tank. After leaving the tank the felt is once again looped to cool the product. Crushed rock or mica is applied with bituminous material to produce roofing shingles.

C. EMISSIONS AND CONTROLS

Figure 7.17.2 shows the points of emissions from asphalt saturators. The emissions are a mixture of asphalt vapors, liquid particulates and water vapors. The machines are large and require hoods with indraft velocities of 200 ft/min or more to capture the vapors and mists. Figure 7.12.2 illustrates the extent of hooding required to achieve positive control of ventilation.

The crushed rock feeder may emit dust and should be hooded and vented to a cyclone or scrubber.

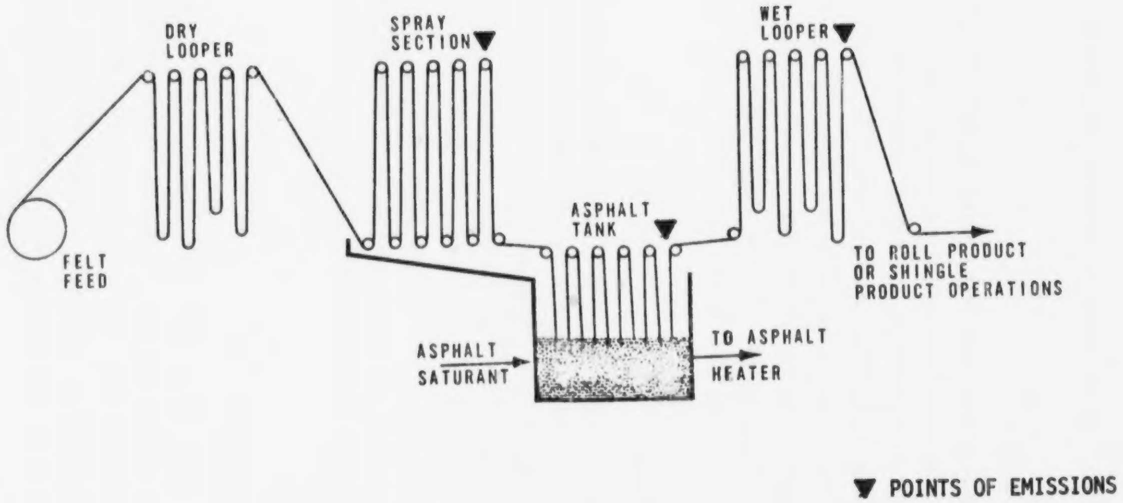

FELT FEED
DRY LOOPER
SPRAY SECTION
ASPHALT TANK
WET LOOPER
TO ROLL PRODUCT OR SHINGLE PRODUCT OPERATIONS
ASPHALT SATURANT
TO ASPHALT HEATER
▼ POINTS OF EMISSIONS

Figure 7.17.1. SCHEMATIC DRAWING OF AN ASPHALT ROOFING FELT SATURATOR (SOURCE: WEISS, Reference 1).

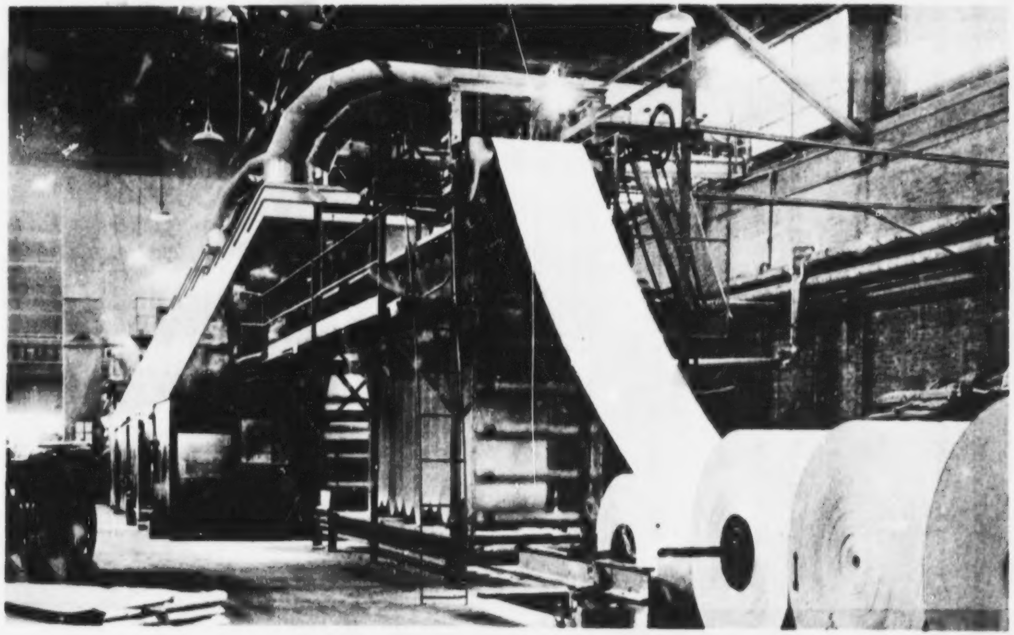


Figure 7.17.2. ASPHALT SATURATOR HOOD AT FELT FEED
(Lloyd A. Fry Roofing Co., Los Angeles, Calif.)
(SOURCE: WEISS, Reference 1)

Due to the physical shape and size of the machines and high indraft velocities at the hoods, large volumes of air are required to capture the air contaminants. Collection devices commonly used are spray scrubbers, baghouses and two-stage low voltage electrical precipitators in combination with spray scrubbers.

The Los Angeles County Air Pollution Control District in tests conducted on three types of air pollution control systems mentioned above report the results shown in Tables 7.17.1, 7.17.2, and 7.17.3.

Table 7.17.1. EMISSIONS FROM A WATER SCRUBBER AND LOW-VOLTAGE, TWO-STAGE ELECTRICAL PRECIPITATOR VENTING AN ASPHALT SATURATOR

	Scrubber inlet	Precipitator inlet	Precipitator outlet
Volume, scfm	20,000	20,234	20,116
Temperature, °F	139	85	82
Emission rate,			
gr/scf	0.416	0.115	0.058
lb/hr	71.4	20	10
Water vapor, %	3.7	4.9	4.8
Collection efficiency	Scrubber, 71%	Precipitator, 50%	Overall, 86%

(SOURCE: WEISS, Reference 1.)

Table 7.17.2. EMISSIONS FROM A BAG FILTER AND CYCLONE SEPARATOR VENTING AN ASPHALT SATURATOR

	Control equipment inlet	Control equipment discharge
Volume, scfm	10,300	10,300
Temperature, °F	217	195
Emission rate,		
gr/scf	0.768	0.289
lb/hr	67.7	25.5
Water vapor, %	6.4	6.8
Collection efficiency, %		62.3

(SOURCE: WEISS, Reference 1.)

Table 7.17.3. EMISSIONS FROM A WATER SCRUBBER VENTING AN ASPHALT SATURATOR

	Scrubber inlet	Scrubber discharge
Volume, scfm	12,000	12,196
Temperature, °F	138	82
Emission rate,		
gr/scf	0.535	0.0737
lb/hr	55.0	7.7
Water, %	2.7	4.2[a]
Collection efficiency, %		86

[a] At 3.7 volume % of water, vapor is saturated air. Other qualitative tests run simultaneously showed no particulate water.

(SOURCE: WEISS, Reference 1.)

While electrical precipitators show greater collection efficiencies than baghouses, critical maintenance problems must be considered. Due to oil deposits on the precipitator components, regular cleaning is mandatory to maintain collection efficiency. Regular checks are also necessary to assure timely replacement of cracked wires and insulators. Oil particles may build up in baghouses and blind the filter bags to cause increase in pressure drop and decrease in vapor pickup at the hoods. Baghouses can be used in series with a cyclone separator downstream to collect reentrained oil droplets.

The use of spray scrubbers may not be desirable in areas where air pollution control agency regulations prohibit excessive opacities of emissions. Due to greatly reduced collection efficiency in the one micron particle size range the opacity of the effluent from spray scrubbers can exceed 50%. Tests have shown fairly good efficiencies on a weight basis.

D. INSPECTION POINTS

Plant inspections should be directed at (1) the saturator to determine the effectiveness of the ventilation system which captures the vapors and particulates from the application of the asphalt and (2) the collection device to determine if it is operating efficiently, as indicated by the opacity of emissions. Air Pollution control equipment operating characteristics and maintenance recommendations are described in Chapter 2. The inspector will observe poor pick up at the hood serving the saturator if there are excessive air leakages through holes in the duct work, plugged lines or other maintenance problems which can hinder the gas flow in the system. Methods of quantitatively determining hood indraft velocities are discussed in Chapter 5.

Observations from outside the plant should be directed at windows and roof monitors which will emit opaque vapors if the air pollution control system is not in use.

Asphalt saturators can be a source of nuisance complaints as well as violations of opacity regulations.

REFERENCE

1. Weiss, S. M. Asphalt Roofing Felt-Saturators. In: Air Pollution Engineering Manual, J. A. Danielson (ed.). Cincinnati, DHEW, PHS, National Center for Air Pollution Control and the Los Angeles County Air Pollution Control District. PHS No. 999-AP-40. 1967.

XVIII. ASPHALTIC CONCRETE BATCHING OPERATIONS

A. DESCRIPTION OF SOURCE

Asphaltic concrete is produced by combining asphalt cement with sized, dry aggregate and fines to form a workable mixture for use in a variety of paving applications. At ambient temperatures asphalt cement is a solid tarlike petroleum product. It is heated to between 275° and 325°F until it flows sufficiently to thoroughly permeate the aggregate to form the mix specification desired. Aggregate is the name applied to crushed rock, sand, gravel and fines which provide the properties of compressive strength and wear desired in concrete. Batching plants are common to many construction sites and are portable to some degree. Since large quantities of rock, sand and gravel are used in the batching operation, batching plants are found near quarries and gravel beds.

The batching plant consists of a rotary drier, aggregate bins, materials handling equipment, screens, asphaltic cement storage and heating equipment, weigh boxes, and fuel storage. Some form of air pollution control equipment is used ranging from cyclone separators and scrubbers to baghouses.

Losses from uncontrolled rotary driers average about 5 pounds of dust per ton of material processed.(1) Tests conducted by the Los Angeles County Air Pollution Control District have shown dust loadings in dryer effluent as high as 6,700 pounds/hour(2) prior to entering the primary separator. Dust loadings can often reach 1,000 pounds/hour(1) or more from equipment controlled only by cyclones.

B. PROCESS DESCRIPTION

A typical equipment train for hot asphalt batching plants consists of sand and aggregate storage bins feeding into a bucket elevator or cold elevator which discharges into a rotary dryer, which may be either gas or oil fired. Depending on the proportions of the different sizes of aggregate the dryer temperature will range from 250° to 350°F. The dried aggregate discharges to the hot elevator which feeds into vibrating screens for size classification (Figure 7.18.1) and interim storage. Varying amounts of rock, sand and fines are then weighed and dropped into the pug mill where the asphalt cement is added. Finally, after thorough mixing the batch is dropped into trucks for transport to the job site. In a continuous-type plant the aggregate and asphalt are introduced into the mixer and the mix discharges continuously. Exhaust systems usually serve the hot and cold elevators, the dryer and the weigh hopper-storage bin combination. Figure 7.18.2 illustrates a typical system.

The Asphalt Institute classifies paving mixes according to the relative amounts of coarse aggregate, fine aggregate and mineral dust used for various desired specifications. By definition, coarse aggregate is retained on a No. 8 sieve (up to 2 1/2"); fine aggregate will pass a No. 8 sieve; mineral dust will pass a No. 200 sieve. Table 7.18.1 describes the standard U.S. and Taylor Sieve Series. The difference is that the U.S. Sieve is identified by millimeters or microns while the Taylor Sieves are identified by the nominal meshes per linear inch. Table 7.18.2 is a summary of mixes recommended by the Institute. The numbers represent the amount of material that will pass a given sieve opening. For example, 100 percent of MIX Type 1a will pass through a 2 1/2 inch opening.

Asphalt cement is a thermoplastic material which decreases in viscosity as it is heated. A range of specifications for describing the quality of the asphalt is shown in Table 7.18.3. These include: penetration tests to determine relative hardness at ambient temperature (77°F or 25°C); viscosity tests, conducted at temperatures of 275°F (135°C), to establish ease of flow; flash point to determine safe heating limits; thin film test to determine the degree of hardening which may occur during the plant

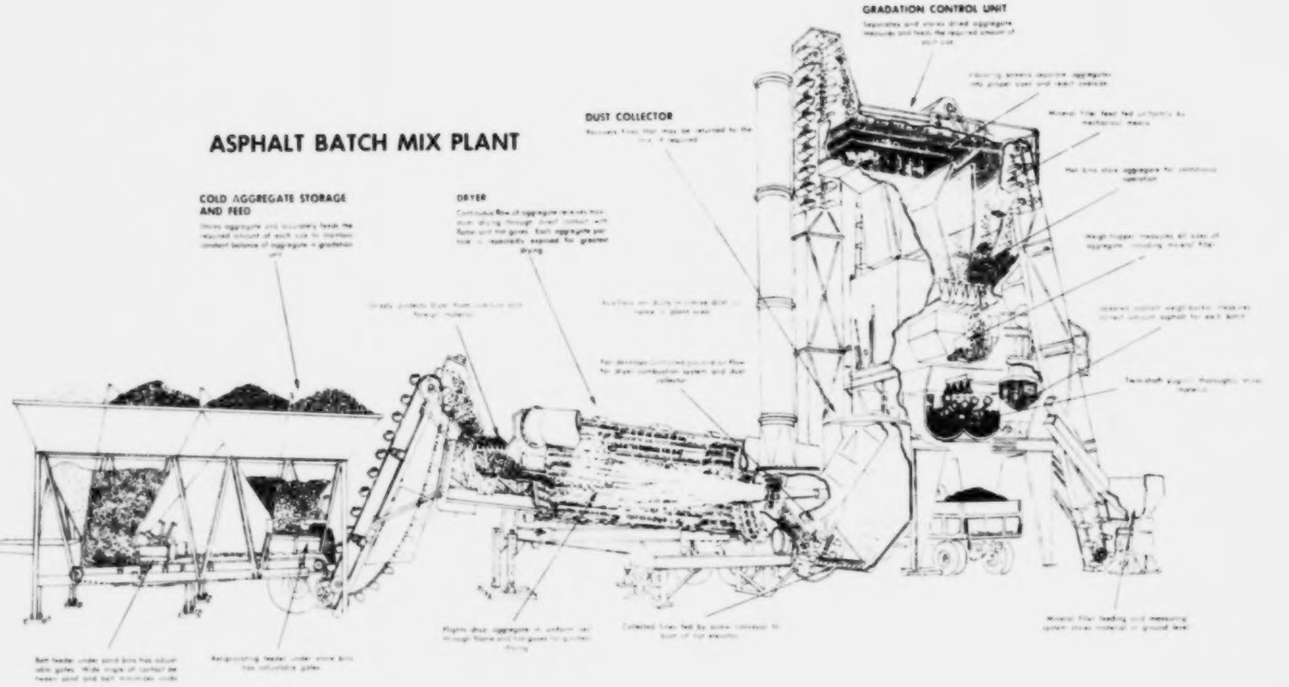
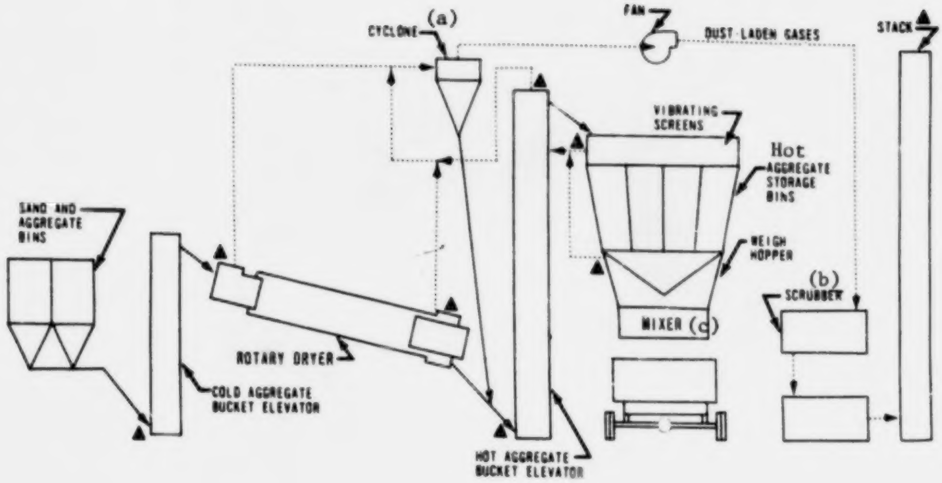

ASPHALT BATCH MIX PLANT
COLD AGGREGATE STORAGE AND FEED
DRYER
DUST COLLECTOR
GRADATION CONTROL UNIT
Separates and stores dried aggregate, measures and feeds the required amount of each size

Figure 7.18.1. ASPHALT BATCH PLANT WITH A CYCLONE TYPE DUST COLLECTOR (SOURCE: The Asphalt Institute, Reference 3)


CYCLONE
(a)
FAN
DUST LADEN GASES
STACK
VIBRATING SCREENS
Hot AGGREGATE STORAGE BINS
SAND AND AGGREGATE BINS
WEIGH HOPPER
(b)
SCRUBBER
MIXER (c)
ROTARY DRYER
COLD AGGREGATE BUCKET ELEVATOR
HOT AGGREGATE BUCKET ELEVATOR

(a) Primary Collector

(b) Secondary Collector

(c) Mineral Filler & Asphalt Cement Added at Mixer

▲ Emission Points

Figure 7.18.2. FLOW DIAGRAM OF A TYPICAL HOT-MIX ASPHALT PAVING BATCH PLANT (SOURCE: Danielson, Reference 2)

Table 7.18.1. STANDARD U.S. AND TYLER SCREEN SCALES
(SOURCE: Public Health Service, Reference 4)

Nominal Aperture width		U.S. Standard	Tyler	Nominal Aperture width		U.S. Standard	Tyler
microns	inches*			microns	inches*		
1	.00004	12500	-	420	.0165	40	-
2.5	.0001	5000	-	495	.0195	-	32
5	.0002	2500	-	500	.0197	35	-
10	.0004	1250	-	589	.0232	-	28
20	.0008	625	-	590	.0232	30	-
37	.0014	400	-	701	.0276	-	24
43	.0017	-	325	710	.0280	25	-
44	.0017	325	-	833	.0328 (1/32)	-	20
53	.0021	270	270	840	.0331	20	-
61	.0024	-	250	991	.0390	-	16
62	.0024	230	-	1000	.0394	18	-
74	.0029	200	200	1168	.0460 (3/64)	-	14
88	.0035	170	-	1190	.0469	16	-
89	.0035	-	170	1397	.0550	-	12
104	.0041	-	150	1410	.0555	14	-
105	.0041	140	-	1651	.0650 (1/16)	-	10
124	.0049	-	115	1680	.0661	12	-
125	.0049	120	-	1981	.0780 (5/64)	-	9
147	.0058	-	100	2000	.0787	10	-
149	.0059	100	-	2362	.093 (3/32)	-	8
175	.0069	-	80	2380	.0937	8	-
177	.0070	80	-	2794	.110 (7/64)	-	7
208	.0082	-	65	2830	.111	7	-
210	.0083	70	-	3327	.131 (1/8)	-	6
246	.0097	-	60	3360	.132	6	-
250	.0098	60	-	3962	.156 (5/32)	-	5
295	.0116	-	48	4000	.157	5	-
297	.0117	50	-	4699	.185 (3/16)	-	4
350	.0138	45	-	4760	.187	4	-
351	.0138	-	42	6680	.263 (1/4)	-	3
417	.0164 (1/64)	-	35				

*Numbers in parentheses indicate approximate fractions of an inch.

Table 7.18.2. MIX COMPOSITIONS
(SOURCE: Air Pollution Engineering Manual, Reference 2)

Mix[1] Type	2½ in.	1½ in.	1 in.	¾ in.	½ in.	⅜ in.	#4	#8	#16	#30	#50	#100	#200	Percent[2] Asphalt
I a	100	35-70		0-15				0-5					0-3	3.0-4.5
II a						100	45-85	5-20					0-4	4.0-5.0
II b					100	70-100	20-40	5-20					0-4	4.0-5.0
II c				100	70-100	45-75	20-40	5-20					0-4	3.0-6.0
II d			100	70-100		35-60	15-35	5-20					0-4	3.0-6.0
II e		100	70-100	50-80		25-60	10-30	5-20					0-4	3.0-6.0
III a					100	75-100	35-55	20-35		10-22	6-16	4-12	2-8	3.0-6.0
III b				100	75-100	60-85	35-55	20-35		10-22	6-16	4-12	2-8	3.0-6.0
III c				100	75-100	60-85	30-50	20-35		5-20	3-12	2-8	0-4	3.0-6.0
III d			100	75-100		45-70	30-50	20-35		5-20	3-12	2-8	0-4	3.0-6.0
III e		100	75-100	60-85		40-65	30-50	20-35		5-20	3-12	2-8	0-4	3.0-6.0
IV a					100	80-100	55-75	35-50		18-29	13-23	8-16	4-10	3.5-7.0
IV b				100	80-100	70-90	50-70	35-50		18-29	13-23	8-16	4-10	3.5-7.0
IV c			100	80-100		60-80	48-65	35-50		19-30	13-23	7-15	0-8	3.5-7.0
IV d		100	80-100	70-90		55-75	45-62	35-50		19-30	13-23	7-15	0-8	3.5-7.0
V a					100	85-100	65-80	50-65	37-52	25-40	18-30	10-20	3-10	4.0-7.5
V b				100	85-100		65-80	50-65	37-52	25-40	18-30	10-20	3-10	4.0-7.5
VI a					100	85-100		65-78	50-70	35-60	25-48	15-30	6-12	4.5-8.5
VI b				100		85-100		65-80	47-68	30-55	20-40	10-25	3-8	4.5-8.5
VII a						100	85-100	80-95	70-89	55-80	30-60	10-35	4-14	7.0-11.0
VIII a							100	95-100	85-98	70-95	40-75	20-40	8-16	7.5-12.0

[1] See article 4.0.7

[2] By weight as a percentage of total mix.

Table 7.18.3. ASPHALT TEST SPECIFICATIONS

TEST NAME	TEST METHOD	
	AASHO* Test	ASTM** Test
1. Penetration	T 49	D 5
2. Viscosity	T 201	D 2170
3. Flash Point	T 48	D 92
4. Thin Film Test	T 179	D 1754
5. Ductility Test	T 51	D 113
6. Soluability Test	T ff	D 4
7. Specific Gravity	T 43	D 70
8. Softening Point	T 53	D 36

* American Association of State Highway Officials

** American Society for Testing Materials mixing operation; ductility tests to indicate the adhesive quality of asphalt and temperature susceptibility; solubility tests to determine the active cementing constituents of the asphalt by establishing the bitumen content; specific gravity, the ratio of weight of a volume of water at the indicated temperature, to make volume corrections at elevated temperatures and to determine voids in asphalt paving mixes; softening point tests, for asphalt grades harder than those used for paving, to indicate the temperatures at which they reach an arbitrary degree of softening.

C. CONTAMINANTS EMITTED

As in all operations employing rotating kilns or dryers, entrainment of dust in the products of combustion due to product drying is the primary source of contaminants. Secondary sources are materials handling equipment and sizing equipment. In the typical plant shown in Figure 7.18.2, dust pickup points served by local exhaust systems are indicated.

Table 7.18.4 shows the results of tests taken from plants with oil-fired dryers indicating the high dust loading in the exhaust gas and in the vent lines which capture dust from elevators and shakers. The materials handling equipment accounts for as much as 2,000 pounds/hour exclusive of dust from the rotary dryer.

Particle size distribution of the dust generated is an important factor in the selection of adequate air pollution control equipment. Results of investigations made of the distribution of particle size versus percent by weight from drier exhaust and vent lines are shown in Figure 7.18.3. This study indicated that as much as 89 percent of the particles may fall below 10 microns. The design of the mix which specifies the aggregate and fines required will affect the particle size distribution and the total dust loading of the exhaust.

Table 7.18.4. DUST AND FUME DISCHARGE FROM ASPHALT BATCH PLANTS (SOURCE: Sheehy et. al., Reference 4)

Test No.	C-426		C-537	
Batch plant data				
Mixer capacity, lb	6,000		6,000	
Process weight, lb/hr	364,000		346,000	
Drier fuel	Oil, PS300		Oil, PS300	
Type of mix	City street, surface		Highway, surface	
Aggregate feed to drier, wt %				
+10 mesh	70.8		68.1	
-10 to +100 mesh	24.7		28.9	
-100 to +200 mesh	1.7		1.4	
-200 mesh	2.8		1.6	
Dust and fume data	Vent line[a]	Drier	Vent line[a]	Drier
Gas volume, scfm	2,800	21,000	3,715	22,050
Gas temperature, °F	215	180	200	430
Dust loading, lb/hr	2,000	6,700	740	4,720
Dust loading, grains/scf	81.8	37.2	23.29	24.98
Sieve analysis of dust, wt %				
+100 mesh	4.3	17.0	0.5	18.9
-100 to +200 mesh	6.5	25.2	4.6	32.2
-200 mesh	89.2	57.8	94.9	48.9
Particle size of -200 mesh				
0 to 5 μ, wt %	19.3	10.1	18.8	9.2
5 to 10 μ, wt %	20.4	11.0	27.6	12.3
10 to 20 μ, wt %	21.0	11.0	40.4	22.7
20 to 50 μ, wt %	25.1	21.4	12.1	49.3
> 50 μ, wt %	14.2	46.5	1.1	6.5

[a] Vent line serves hot elevator, screens, bin, weigh hopper, and mixer.

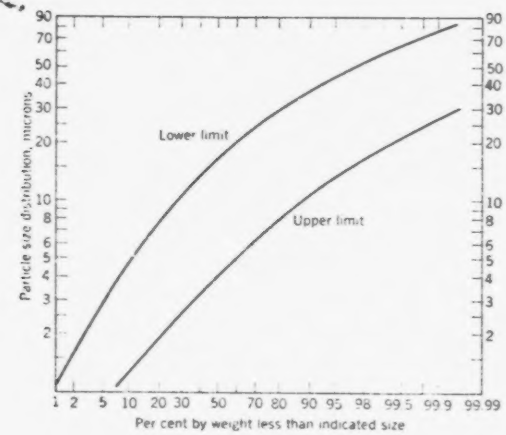


Figure 7.18.3. COMPOSITE ASPHALT PLANT DUST PARTICLE SIZE DISTRIBUTION
(SOURCE: JAPCA, Reference 5)

Collection and control systems for batch or continuous plants usually have primary and secondary dust collection devices and in some instances a tertiary device is added to the collection train. The air pollution control system is usually comprised of cyclone separators (singly or in multiple units) and scrubbers or baghouses in series. In addition to collecting dust to meet air pollution control regulations, the dust collected can be recycled to the process.

Cyclones have a reasonable efficiency for larger particle sizes ($>$ 20 microns) with a 2 to 3 inches water pressure drop. Since as much as 89 percent of the dust can be < 10 microns, additional high efficiency collection is required. High efficiency mechanical collectors such as multiclones, which can reach 90 percent efficiency in the 5 to 10 micron particle size range with a pressure drop of 4 to 6 inches water gauge, are available. These devices may not meet the requirements of many agencies having process weight or exhaust grain loading regulations.

The next higher order of efficiency of air pollution control equipment is wet collectors. A wide range of configurations, spray pattern designs and gas path designs are available with efficiencies for the low particle size range reaching greater than 99 percent (see Table 7.18.5). Water requirements range from 4 to 10 GPM/1,000 ft.(3) of gas entering the scrubber and the water pressure varies from 50 to 100 psi. A wide range of pressure drops from 3 to 10 inches water may occur.

As new regulations which decrease maximum allowable dust emissions are enacted, baghouses will come into greater use as the final collector in the dust removal train. Efficiencies of overall dust collection with this equipment is 99+ percent at a pressure drop of 4 to 5 inches water. Air-to-cloth ratios of 2/1 to 6.25/1 (2 ft.^{3} of air per ft.^{2} of cloth to 6.25 ft.^{3} of air per ft.^{2} of cloth) are required depending on the fabric used as the filter media and bag cleaning procedures.(5)

Table 7.18.5. TEST DATA FROM HOT-MIX ASPHALT PAVING PLANTS CONTROLLED BY SCRUBBERS (SOURCE: Danielson, Reference 2)

Test No.	Scrubber inlet dust loading, lb/hr	Stack emission, lb/hr	Aggregate fines rate,[a] lb/hr	Water-gas ratio, gal/1,000 scf	Overall scrubber efficiency, wt %	Type of scrubber[b]	Type of drier fuel	Production rate, tons/hr	Gas effluent volume, scfm
C-357	940	20.7	9,550	6.62	97.8	C	Oil	183.9	23,100
C-82	427	35.6	4,460	3.94	91.6	C	Oil	96.9	19,800
C-379	4,110	37.1	8,350	6.38	99.1	C	Oil	174.0	26,200
C-355	2,170	47.0	14,000	6.81	97.8	C	Oil	209.1	25,700
C-372B	121	19.2	2,290	10.99	84.2	C	Oil	142.9	18,200
C-372A	76	10.0	2,840	11.11	86.8	C	Gas	158.0	18,000
C-369	352	24.4	4,750	5.41	93.0	C	Oil	113.0	16,100
C-393	4,260	26.9	4,050	12.01	99.3	T	Oil	92.3	19,500
C-354	--	27.8	6,370	6.10	--	T	Oil	118.4	7,720
C-185	1,640	21.3	5,220	19.40	98.7	T	Oil	137.8	18,700
C-173	--	31.0	8,850	20.40	--	T	Oil	184.2	17,000
1	--	33.5	7,520	11.01	--	T	Oil	144.6	23,700
C-379	3,850	30.3	6,500	5.92	99.2	C	Gas	191.3	28,300
C-337	305	13.6	2,510	11.11	95.5	C	Oil	114.6	24,300
2	--	21.1	3,730	7.28	--	T	Gas	124.4	15,900
C-234	372	21.2	2,530	5.70	94.3	T	Gas	42.0	17,200
C-426	2,620	25.5	10,200	7.75	99.0	C	Oil	182.0	22,000
C-417	560	39.9	3,050	2.94	92.8	C	Oil	138.9	24,600
C-425	485	32.9	2,890	4.26	93.2	C	Oil	131.4	18,000
3	--	25.5	6,590	6.60	--	C	Gas	131.7	18,200
C-385	212	17.5	4,890	4.56	91.7	C	Oil	174.3	20,000
C-433	266	11.0	5,960	8.12	95.8	C	Gas	114.5	19,600
C-422(1)	--	26.6	7,140	4.90	--	C	Oil	198.0	21,000
C-422(2)	--	37.0	3,340	3.02	--	C	Oil	152.0	22,200
C-418	3,400	30.8	9,350	8.90	99.1	T	Oil	116.5	17,100
Averages		26.7	5,900		94.9				

[a] Quantity of fines (minus 200 mesh) in dryer feed.

[b] C = Multiple centrifugal-type spray chamber.
T = Baffled tower scrubber.

D. INSPECTION POINTS

Asphaltic concrete batching plants that operate in industrial or mixed industrial/residential areas can be the subject of nuisance complaints. The large quantities of small particle size dust emitted from plants with only cyclones or inadequately sized wet collectors can carry relatively long distances under certain meteorological conditions.

While the dust emitted from the batching plant is not toxic or potentially destructive to vegetation or finished surfaces, the potential health hazard that may occur from any finely divided material and possible soiling effects must be considered. One hot asphalt plant with only a primary separator can emit 200 to 2,000 pounds of fine dust per hour. Dust from asphalt plants settling on automobiles and other stationary items indicates that the air pollution control equipment is either not in use or is not operating properly.

Inspection of a batching plant should determine the capability of existing equipment to meet emission control regulations. The enforcement officer should:

(1) Check type of air pollution control equipment installed and observe emissions.

(2) Check basic equipment, suction points, duct work, etc., for leaks.

(3) Check ancillary equipment (boilers, mixers, etc.) for emissions and odors.

(4) Check plant area for potential sources of fugitive dust (storage areas, yard area, etc.).

(5) Check equipment capacity, operating schedule and plant throughput.

The enforcement officer should determine whether equipment which has been accepted as capable of meeting an emission limit is operating properly and complying with that limit, assuming a cyclone-scrubber control system is used. He should:

(1) Check water pressure and flow rate.

(2) Check for leaks in duct work.

(3) Check loading area for dust or odors.

(4) Check methods used to minimize fugitive dust emissions in the yard.

(5) Check type of fuel utilized in dryer and boiler.

(6) Check temperature of asphalt cement (assuming a cyclone-baghouse system is used).

(7) Check condition of bags for tears and blinding.

(8) Check pressure drop across baghouse to determine if it is higher than design specifications.

The enforcement officer should determine the potential of the batching plant to create a nuisance problem:

(1) Discuss with plant management dust and odors caused by overload, plugging or upset conditions.

(2) Discuss odors that may result from mixing operations.

(3) Discuss dust problems that may result from trucks in yard area, storage piles, etc.

Visual observation can provide a qualitative measure of the dust emitted from a batch plant but only stack tests will give quantitative results. Most batch plants should be tested if specific regulations regarding process weight or allowable grain loading of exhaust gases are in effect. The enforcement officer can then make comparative readings of the dust emissions to determine if the plant is in compliance.

REFERENCES

1. Control Techniques for Particulate Air Pollutants. Washington, D.C., DHEW, PHS, NAPCA, January 1969.
2. Danielson, J. A., and R. S. Brown, Jr. Hot Asphalt-Mix Paving Batch Plants. In: Air Pollution Engineering Manual, J. A. Danielson (ed.). Cincinnati, DHEW, PHS, National Center for Air Pollution Control and the Los Angeles County Air Pollution Control District. PHS No. 999-AP-40. 1967.
3. The Asphalt Plant Manual. The Asphalt Institute. Series No. 3 (MS-3). March 1967.
4. Sheehy, J. P., W. C. Achinger, and R. A. Simon. Handbook of Air Pollution, DHEW, PHS, NCADC No. 999-AP-44. (No date).
5. Air Pollution Control Practices for Hot Mix Asphalt Paving Batch Plants. J. Air Pollution Control Assoc., Vol. 19, No. 12, December 1969.

GLOSSARY

A

ABSORBER: A device utilized to extract selectively one or more elements of a gas stream from others by absorption in a liquid medium. Usually the process is performed in cylindrical towers packed with an inert material thus providing a large surface area for intimate contact between the rising gas and the falling liquid. (The process may also be carried out in a tower containing perforated trays in which the rising gas bubbles through the layer of liquid on the trays.)

ABSORPTION: A process in which one or more constituents are removed from a gas stream by dissolving them in a selective liquid solvent. This may or may not involve a chemical change.

ACCUMULATOR: A vessel for the temporary storage of a gas or liquid; usually used for collecting sufficient material for a continuous charge to a refining process.

ACID SLUDGE: The residue left after treating petroleum oil with sulfuric acid for the removal of impurities. It is a black, viscous substance containing the spent acid and impurities which have been separated from the oil.

ACID TREATMENT: An oil-refining process in which unfinished petroleum products, such as gasoline, kerosene, diesel fuel, and lubricating stocks, are contacted with sulfuric acid to improve color, odor, and other properties.

ACIDULATE: To make acid, especially slightly acid; to treat with acid.

ADDITION REACTION: Direct chemical combination of two or more substances to form a single product, such as the union of ethylene and chlorine to form ethylene dichloride:

$$C_2H_4 + Cl_2 \longrightarrow C_2H_4Cl_2$$

ADIABATIC LAPSE RATE: The rate at which a given mass of air lifted adiabatically (without loss or gain of heat) cools due to the decrease of pressure with increasing height, 5.4°F/1000 ft (9.7°C/km).

ADIABATIC PROCESS: A thermodynamic change of state of a system in which there is no transfer of heat or mass across the boundaries of the system.

ADIABATIC TEMPERATURE: (Combustion) The theoretical temperature that would be attained by products of combustion provided the entire chemical energy of the fuel, the sensible heat content of the fuel, and combustion air above the ambient temperature were transferred to the products of combustion. This assumes (1) that combustion is complete, (2) that there is no heat loss, (3) that there is no dissociation of the gaseous compounds formed, and (4) that inert gases play no part in the reaction.

ADSORPTION: A reaction in which one or more constituents (adsorbates) are removed from a gas stream by contacting and adhering to the surface of a solid (adsorbent). Periodically the adsorbent must be regenerated to remove the adsorbate.

AEROSOL: A colloidal system in which particles of solid or liquid are suspended in a gas. There is no clear-cut upper limit to the particle size of the dispersed phase in an aerosol, but as in all other collodial systems, it is commonly set at 1 micro-meter. Haze, most smoke, and some fogs and clouds may be regarded as aerosols.

AFTERBURNER: A burner located so that combustion gases are made to pass through its flame in order to remove smoke and odors.

AGGLOMERATION: Groups of fine particles clinging together to form a larger particle.

AIR ATOMIZING OIL BURNER: A burner in which oil is atomized by compressed air which is forced into and through one or more streams of oil thus breaking it into a fine spray.

AIR CURTAIN DESTRUCTOR: A device employing an air blower with pit incinerator. Excess oxygen and turbulence result in apparent complete combustion, leaving no residue unburned carbon (smoke) nor odorous hydrocarbons. The device has been satisfactorily demonstrated for disposal of low-ash, high-Btu waste, such as trees, tree trunks, brush (but not leaves), and wooden crating material. Excessive pollution results when materials such as automobile tires, cushions, and other non-wood wastes are burned.

AIR HEATER OR AIR PREHEATER: Heat transfer apparatus through which combustion air is heated by a medium of higher temperature, such as the products of combustion or steam.

ALKYLATION: In petroleum refining, usually the union of an olefin (ethylene through pentene) with isobutane to yield high-octane, branched-chain paraffinic hydrocarbons. Alkylation may be accomplished by thermal and catalytic reactions. Alkylation of benzene and other aromatics with olefins yields alkyl aromatics.

ALUMINA: Aluminum oxide (Al_2O_3), an intermediate product in the production of aluminum. This oxide also occurs widely in nature as corundum.

AMBIENT AIR: That portion of the atmosphere, external to buildings, to which the general public has access.

ANODE: In aluminum production, the positively charged carbon terminal in the reduction cell or pot. Oxygen is attracted to the anode where it combines with carbon plus any impurities, such as sulfur, which may be present. The anode is consumed by this process and must be replaced periodically.

ANTHRACITE COAL: A hard, black, lustrous coal containing a high percentage of fixed carbon and a low percentage of volatile matter. Commonly referred to as "hard coal," it is mined in the United States, mainly in eastern Pennsylvania, as well as in small quantities in other states.

AREA SOURCE: Any small residential, governmental, institutional, commercial, or industrial fuel combustion operations, as well as on-site waste disposal and transportation sources (see point source).

ASH: The noncombustible solid matter in fuel.

ASH-FREE BASIS: The method of reporting fuel analysis whereby ash is deducted and other constituents are recalculated to total 100 percent.

ASME: The American Society of Mechanical Engineers.

ASPIRATING BURNER: A burner in which the fuel in a gaseous or finely divided form is burned in suspension. The air of combustion is supplied by drawing it through one or more openings by the lower static pressure created by the velocity of the fuel stream.

ASTM: The American Society for Testing and Materials.

ATOMIZER: A device by means of which a liquid is reduced to a very fine spray.

ATMOSPERIC PRESSURE: The pressure due to the weight of the atmosphere. Normal atmospheric pressure at sea level is approximately 14.7 p.s.i. or 29.92 inches of mercury.

AVAILABLE HEAT: The quantity of useful heat per unit of fuel available from complete combustion after deducting dry flue gas and water vapor losses.

B

BAGASSE: Sugar cane from which the juice has been essentially extracted.

BAG FILTER: A device containing one or more cloth bags for recovering particles from the dust-laden gas which is blown through it.

BAGHOUSE: Structures containing several bag filters (see bag filters).

BAG-TYPE COLLECTOR: A filter wherein the cloth filtering medium is made in the form of cylindrical bags.

BANKING: Burning solid fuels on a grate at rates sufficient to maintain ignition only.

BARK BOILER: A combustion unit designed to burn mainly bark and wood residues, used to produce steam for process or electrical energy.

BAROMETRIC CONDENSER: An inexpensive direct contact condenser used when condensate recovery is not a factor. In this type of condenser, steam rises into a rain of cooling water, and both condensed steam and water flow out of the bottom of the condenser, maintaining a partial vacuum in the condenser.

BASE STOCK: A sheet, usually produced from unbleached kraft pulp, formed into linerboard on a fourdrinier machine.

BATCH FED INCINERATOR: An incinerator that is charged with refuse periodically, the charge being allowed to burn down or burn out before another charge is added.

BINDER: See core binder.

BITUMINOUS COAL: Soft coal, dark brown to black in color, having a relatively high proportion of gaseous constituents and usually burning with a smoky luminous flame.

BLACK LIQUOR: Spent chemical solution which is formed during the cooking of wood pulp in the digester. The black liquor is burned as a fuel in the recovery furnace.

BLAST FURNACE: A shaft furnace in which solid fuel is burned with an air blast to smelt ore.

BLEEDER: A bypass or relief valve used to relieve excess pressure.

BLISTER COPPER: An impure intermediate product in the refining of copper, produced by blowing copper bearing material in a converter; the name is derived from the large blisters on the cast surface that result from the liberation of SO_2 and other gases.

BLOWBACK: The difference between the pressure at which a safety valve opens and at which it closes, usually about three percent of the pressure at which the valve opens.

BLOWDOWN: Hydrocarbons purged during refinery shutdowns and startups which are manifolded for recovery, safe venting, or flaring.

BOILER: A closed pressure vessel in which the liquid, usually water, is vaporized by the application of heat.

BOILER HORSEPOWER: A unit of rate of water evaporation. One boiler horsepower equals the evaporation of 34.5 lb. of water per hour from a temperature of 212°F into dry saturated steam at the same temperature (equivalent to 33,472 Btu per hour).

BRASSESS: Copper-based alloy of 60-65% copper. Alloying material is usually zinc.

BREAKER: In anthracite mining, the structure in which the coal is broken, sized, and cleaned for market. Also known as a coal breaker. A machine used for the primary reduction of coal, ore, or rock.

BREECHING: A sheet-iron or sheet-metal casing at the end of boilers for conveying the smoke from the flues to the smokestack.

BRIGHTENING: The process of producing bright stock (see bright stock).

BRIGHT STOCK: Refined high viscosity lubricating oils usually made from residual stocks by suitable treatment, such as a combination of acid treatment or solvent extraction with dewaxing or clay finishing.

BRITISH THERMAL UNIT (Btu): The mean British thermal unit is 1/180 of the heat required to raise the temperature of one pound of water from 32°F to 212°F at a constant atmospheric pressure. It is about equal to the quantity of heat required to raise one pound of water 1°F. A Btu is essentially 252 calories.

BRONZES: Copper based alloy of 85-90% copper. Alloying material is usually tin.

BUNKER C OIL: Residual fuel oil of high viscosity commonly used in marine and stationary power plants (No. 6 fuel oil).

BURNER: A device for the introduction of fuel and air into a furnace at the desired velocities, turbulence, and concentration to establish and maintain proper ignition and combustion of the fuel.

BUSS (BUSBAR): A heavy metal conductor, usually copper, for high amperage electricity.

BUSTLE PIPE: In steel making, a metal tube of large diameter which surrounds a blast furnace at a level a little above the tuyeres; it is lined with refractory material and distributes the hot air from the blast stoves to the pipes (goosenecks) which carry the air to the tuyeres.

C

CALCINE: Ore or concentrate which has been treated by calcination or roasting and which is ready for smelting.

CALCINING: Roasting of ore in an oxidizing atmosphere usually to expel sulfur or carbon dioxide. If sulfur removal is carried to practical completion, the operation is termed "sweet roasting"; if all CO_2 is removed, the operation is termed "dead roasting."

CALORIE: The mean calorie is 1/1000 of the heat required to raise the temperature of one gram of water from 0°C to 100°C at a constant atmospheric pressure. It is about equal to the quantity of heat required to raise one gram of water 1°C.

CARBONIZATION: The process of converting coal to carbon in the absence of air by using intense heat to remove volative ingredients.

CARBON LOSS: The loss representing the unliberated thermal energy caused by failure to oxidize some of the carbon in the fuel.

CARCINOGENIC: Producing or tending to produce cancer.

CARRYOVER: The chemical solids and liquid entrained in the steam from a boiler or effluent from a fractionating column, absorber, or reaction vessel.

CATALYST: A substance capable of changing the rate of a reaction without itself undergoing any net change.

CATALYTIC CRACKING: The conversion of high boiling hydrocarbons into lower boiling substances by means of a catalyst which may be used in a fixed bed, moving bed, or fluid bed. Natural or synthetic catalysts are employed in bead, pellet, or powder form. Feedstocks may range from naphtha cuts to reduced crude oils.

CATHODE: In aluminum production, the negatively charged terminal of the reduction cell to which the aluminum migrates. The terminal consists of the carbon lining that makes up the bottom of the cell.

CAVING: In metal mining, caving implies the dropping of the over-burden as part of the system of mining.

CHARGING: Feeding raw material into an apparatus, for example, into a furnace, for treatment or conversion.

CHLOROSIS: A diseased condition in green plants marked by yellowing or blanching of the leaves.

CINDERS: Particles not ordinarily considered as fiy ash or dust because of their greater size; these particles consist essentially of fused ash and/or unburned matter.

CLEANING FIRES: The act of removing ashes from the fuel bed or furnace.

CLINKERS, CEMENT: The glassy, stony, lump-like product of fusing together clay and limestone as the first stage in the manufacture of portland cement.

COAL DESULFURIZATION: See desulfurization.

COAL GAS: Gas formed by the destructive distillation of coal.

COAL TAR: A black viscous liquid formed as a by-product from the distillation of coal.

COKE: Bituminous coal from which the volatile constituents have been driven off by heat so that the fixed carbon and the ash are fused together.

COKE BREEZE: Fine coke particles leaving the coke quencher with the quenched coke by conveyor. The particles are very fine and may be blown away.

COKE, PETROLEUM: The solid carbonaceous residue remaining as the final product of the condensation processes in cracking. It consists of highly polycyclic aromatic hydrocarbons very poor in hydrogen. It is used extensively in metallurgical processes. Calcination of petroleum coke can yield almost pure carbon or artificial graphite suitable for production of electrodes, motor brushes, dry cells, etc.

COKING: 1. Carbonization of coal by destructive distillation. 2. In petroleum refining: any cracking process in which the time of cracking is so long that coke is produced as the bottom product; thermal cracking for conversion of heavy, low-grade oils into lighter products and a residue of coke; or the undesirable building up of coke or carbon deposits on refinery equipment.

COLLECTION EFFICIENCY: The ratio of the weight of pollutant collected to the total weight of pollutant entering the collector.

COLLOID: 1. A substance composed of extremely small particles, ranging from 0.005 micro-meters to 0.2 micro-meters, which when mixed with a liquid will not settle, but will remain suspended. The colloidal suspension thus formed has properties that are quite different from the simple solution of the two substances. 2. In fuel burning, a finely divided organic substance which tends to inhibit the formation of dense scale and results in the deposition of sludge, or causes it to remain in suspension, so that it may be blown from the boiler.

COLLOIDAL FUEL: Mixture of fuel oil and powdered solid fuel.

COMBINATION BOILER: A combustion unit used to produce steam for process or electrical energy which is designed to burn bark and at least one other fuel.

COMBUSTION CONTAMINANTS: Particulate matter discharged into the atmosphere from the burning of any kind of material containing carbon.

COMBUSTION TOWER: Refractory graphite-lined or water-jacketed stainless steel tower in which phosphorus is burned to phosphorus pentoxide.

CONDENSED FUMES: Minute solid particles generated by the condensation of vapors from solid matter after volatilization from the molten state, or generated by sublimation, distillation, calcination, or chemical reaction when these processes create airborne particles.

CONDENSER BOILER: A boiler in which steam is generated by the condensation of a vapor.

CONTACT CONDENSER: A condenser in which coolant, vapors, and condensate are mixed.

CONTINUOUS-FEED INCINERATOR: An incinerator into which refuse is charged in a nearly continuous manner in order to maintain a steady rate of burning.

CONTROL STRATEGY: A combination of measures designed to achieve the aggregate reduction of emissions necessary for attainment and maintenance of a national ambient air quality standard.

CONVECTION: The transmission of heat by circulation of a liquid or a gas. Convection may be natural or forced.

CONVERTER: 1. A furnace in which air is blown through a bath of molten metal or matte, oxidizing the impurities and maintaining the temperature through the heat produced by the oxidation reaction. 2. In nitric acid production, the chamber in which ammonia is converted to nitric oxide and water by reacting it with air over a platinum-rhodium catalyst.

CONVERTING: The process of removing impurities from molten metal or metallic compounds by blowing air through the liquid. The impurities are changed either to gaseous compounds, which are removed by volatilization, or to liquids or solids which are removed as slags.

CORE: The central part of a sand mold as used in foundries. The device placed in a mold to make a cavity in a casting.

CORE BINDER: Organic material added to foundry sand to aid in formation of a strong core for casting. Flour, linseed oil, starch, and resins are among materials used.

CRACKING: Chemical reaction by which large oil molecules are decomposed into smaller, lower-boiling molecules. At the same time, certain of these molecules, which are reactive, combine with one another to give even larger molecules than those in the original stock. The more stable molecules leave the system as cracked gasoline, but the reactive ones polymerize, forming tar and even coke. Cracking may be in either the liquid or vapor phase. When a catalyst is used to bring about the desired chemical reaction, this is called "catalytic cracking"; otherwise, it is assumed to be "thermal cracking" (see catalytic cracking).

CRACKLINGS: The crisp residue left after the fat has been separated from the fibrous tissue in rendering lard or frying or roasting the skin of pork, turkey, duck, or goose.

CRUSHER: A machine for crushing rock or other materials. Among the various types of crushers are the ball mill, gyratory crusher, Hadsel mill, hammer mill, jaw crusher, red mill, rolls, and stamp mill.

CRYOLITE: Sodium aluminum fluoride (Na_3AlF_6) used as an electrolyte in smelting of alumina to provide aluminum.

CULM: The fine refuse from anthracite coal production.

CUPOLA: A vertical shaft furnace used for melting metals, especially grey iron, by having the charge come in contact with the hot fuel, usually metallurgical coke. Metal, coke, and flux are charged from the top of the furnace onto a bed of hot coke through which air is blown.

CURTAIN WALL: A partition wall between chambers in an incinerator under which combustion gases pass.

CYCLONE: A structure without moving parts in which the velocity of an inlet gas stream is transformed into a confined vortex from which centrifugal forces tend to drive the suspended particles to the wall of the cyclone body. The particles then slide down the cyclone wall and are collected at the bottom.

CYCLONE SCRUBBERS: Devices ranging from simple dry cyclones with spray nozzles to multistage devices. All feature a tangential inlet to a cylindrical body.

CYCLONIC SPRAY TOWER: Liquid scrubbing apparatus where sprays are introduced countercurrent to gases for removal of contaminants.

D

DEHYDROGENATION: The removal of hydrogen from a chemical compound; for example, the removal of two hydrogen atoms from butane to make butylene, and the further removal of hydrogen to make butadiene.

DEMISTER (COLLECTOR): 1. A mechanical device used to eliminate finely divided liquid particles from process streams by impaction and agglomeration. 2. Apparatus made of wire mesh or glass fiber and used to eliminate acid mist as in the manufacture of sulfuric acid.

DESTRUCTIVE DISTILLATION: 1. A process of distillation in which an organic compound or mixture is heated to a temperature high enough to cause decomposition. 2. The heating of organic matter when air is not present, resulting in the evolution of volatile matter and leaving char consisting of fixed carbon and ash.

DESULFURIZATION: 1. In coal processing, the removal of sulfur from the coal, often by mechanical cleaning processes. 2. In petroleum refining, removing sulfur or sulfur compounds from a charge stock (oil that is to be treated in a particular unit).

DIFFUSION: The spreading or scattering of a gaseous or liquid material. 1. Eddy diffusion: diffusion caused by turbulent activity in a fluid system. 2. Molecular diffusion: a process of spontaneous intermixing of different substances, attributed to molecular motion and tending to produce uniformity of concentration.

DIRECT-FIRED BOILER: Commonly used to denote a boiler and furnace fired by pulverized coal.

DISPERSION: The dilution of a pollutant by diffusion, or turbulent action, etc. Technically, a two-phase system of two substances, one of which (the dispersed phase) is uniformly distributed in a finely divided state through the second substance (the dispersion medium). Either phase may be a gas, liquid, or solid.

DISTILLATE: The product of distillation obtained by condensing the vapors from a still.

DISTILLATE FUELS: Liquid fuels distilled usually from crude petroleum, except residuals such as No. 5 and No. 6 fuel oil.

DISTILLATE OILS: The lighter oils produced by distilling crude oil.

DISTILLATION: The process of heating a substance to the temperature at which it is converted to a vapor, then cooling the vapor, and thus restoring it to the liquid state.

DOCTOR TREATMENT: Treatment of gasoline with sodium-plumbite solution and sulfur to improve its odor.

DOPES FOR GASOLINES: Materials added in small amounts to gasoline to increase the octane number and thus help to prevent knocking.

DOUBLE DECOMPOSITION: A chemical reaction between two compounds in which part of the first compound becomes united with the remainder of the second, as: $AB + CD = AD + BC$.

DRAFT: A gas flow resulting from the pressure difference between the incinerator, or any component part, and the atmoshpere, which moves the products of combustion from the incinerator to the atmosphere. 1. Natural draft: the negative pressure created by the difference in density between the hot flue gases and the atmosphere. 2. Induced draft: the negative pressure created by the vacuum action of a fan or blower located between the incinerator and the stack. 3. Forced draft: the positive pressure created by the action of a fan or blower, which supplies the primary or secondary air.

DROP ARCH: A refractory construction or baffle which serves to deflect gases in a downward direction.

DROSS: 1. Impurity formed in melted metal. A zinc-and-iron alloy forming in a bath of molten zinc, in galvanizing iron. 2. The scum that forms on the surface of molten metals usually due to oxidation, but occasionally due to the rising of impurities to the surface.

DRUM, FLASH (OR FLASH TOWER): A drum or tower into which the heated outlet products of a preheater or exchanger system are conducted, often with some release in pressure. The purpose of the drum is to allow vaporization and separation of the volatile portions for fractionation elsewhere.

DRY BOTTOM FURNACE: A furnace designed to burn pulverized coal at temperatures low enough to prevent the ash from fusing or slagging.

DUST: Generally particles from 1 to 100 micro-meters in size that become airborne by natural or mechanical means. These particles do not diffuse but will settle under the influence of gravity (see also particle).

DUST COLLECTING FAN: A centrifugal fan which concentrates dust and skims it into a cyclone or hopper.

DUSTLESS LOADING: The amount of dust in a gas, usually expressed in grains per cubic foot or in pounds per thousand pounds of gas (see also grain loading).

E

ECONOMIZER: A heat recovery device designed to transfer heat from the products of combustion to a fluid, usually feedwater for a steam boiler. The water flows through a bank of tubes placed across the flue gases and is heated by these gases prior to entering the boiler.

EFFICIENCY: The ratio of output to input. The efficiency of a steam generating unit is the ratio of the heat absorbed by the water or steam to the heat in the fuel fired, expressed in percent.

EFFLUENT: Any waste material (solid, liquid, gas) emitted by a process.

EFFLUENT WATER SEPARATOR: A container designed to separate volatile organic compounds from waste water prior to discharge or reuse.

ELECTROLYSIS: 1. Chemical change resulting from the passage of an electric current through an electrolyte. 2. Transfer or transport of matter through a medium by means of conducting ions (positively or negatively charged particles). The medium may consist of fused salts or conducting solutions which permit free movement of ions toward the countercharged electrodes immersed in the system.

ELECTROSTATIC PRECIPITATOR: Devices that separate particles from a gas stream by passing the carrier gas between two electrodes across which a unidirectional, high-voltage electrical charge is placed. The particles pass through this field, become charged and migrate to the oppositely charged electrode. Single-stage precipitators are those in which gas ionization and particulate collection are combined into a single step. In the two-stage unit, ionization is achieved by one element of the unit and the collection by the other. Electrostatic precipitators are highly efficient collectors for minute particles.

ELUTRIATOR: A vertical tube through which a gas or fluid passes upward at a specific velocity while a solid mixture whose separation is desired is fed into the top of the column. The large particles which settle at a velocity higher than that of the rising fluid are collected at the bottom of the column, and the smaller particles are carried out of the top of the column with the fluid.

EMISSION: The total amount of a solid, liquid, or gaseous pollutant emitted into the atmosphere from a given source in a given time, and indicated in grams per cubic meter of gas, pounds per hour, or other quantitative measurement.

ENDOTHERMIC REACTION: A reaction which requires the addition of heat for its continuation.

ENTRAINMENT: The process of particulates or other materials being carried along by a gas stream.

EVAPORATOR: Usually a vessel which receives the hot discharge from a heating coil and, by a reduction in pressure, flashes off overhead the light products and allows the heavy residue to collect in the bottom (see flash tower).

EXCESS AIR: Air supplied for combustion in excess of that theoretically required for complete combustion, usually expressed as a percentage of theoretical air, such as "130 percent excess air."

EXOTHERMIC REACTION: A reaction which produces heat.

F

FABRIC FILTER: See bag filter.

FIXED CARBON: That part of the carbon which remains when coal is heated in a closed vessel until the volatile matter is driven off. It is the nonvolatile matter minus the ash.

FEEDSTOCK: Starting material used in a process. This may be raw material or an intermediate product that will undergo additional processing.

FLOATING ROOF: A special tank roof which floats upon the oil in a storage tank.

FLUE: Any duct, passage, or conduit through which the products of combustion are carried to a stack or chimney (see also breeching).

FLUE GAS: The gaseous products of combustion passing from the furnace into the stack.

FLUIDIZED ROASTING: Oxidation of finely ground pyritic minerals by means of upward currents of air, blown through a reaction vessel (fluid bed roaster) with sufficient force to cause the bed of material to expand (boil). Reaction between mineral and air is maintained at a desired exothermic level by control of oxygen entry, by admission of cooling water, or by addition of fuel.

FLUOROSIS: A chronic poisoning resulting from the presence of 0.9 milligrams or more per liter of fluorine in drinking water. Teeth become brittle and opaque white with a mottled enamel.

FLUOROSPAR: A natural calcium fluoride (CaF_2) used as a flux in open hearth steel furnaces and in gold, silver, copper, and lead smelting.

FLUX: 1. In chemistry and metallurgy, a substance that promotes the fusing of minerals or metals or prevents the formation of oxides. 2. A substance added to a solid to increase its fusibility. 3. A substance to reduce melting temperature. 4. Any chemical or rock added to an ore to assist in its reduction by heat, such as limestone with iron ore in a blast furnace.

FLY ASH: In incineration, suspended incombustible particles, charred paper, dust, soot, or other partially incinerated matter, carried in the gaseous products of combustion.

FOOD-GRADE ACID: Phosphoric acid that has been treated for removal of heavy metals and is suitable for use in food products.

FORCED DRAFT: See draft.

FRACTIONAL DISTILLATION: The separation of the components of a liquid mixture by vaporizing and collecting the fractions which condense in different temperature ranges.

FUEL: Any form of combustible matter--solid, liquid, vapor, or gas, excluding combustible refuse.

FUEL-BURNING EQUIPMENT: Any furnace, boiler, apparatus, stack, and all appurtenances thereto, used in the process of burning fuel for the primary purpose of producing heat or power by indirect heat transfer.

FUGITIVE DUST: Solid airborne particulate matter emitted from any source other than a flue or stack.

FUME: Fine solid particles predominately less than 1 micro-meter in diameter suspended in a gas. Usually formed from high-temperature volatilization of metals, or by chemical reaction.

FUMIGATION: Fumigation is an atmospheric phenomenon in which pollution, which has been retained by an inversion layer near its level of emission, is brought rapidly to ground level when the inversion breaks up. High concentrations of pollutant can thus be produced at ground level.

FUMING NITRIC ACID: A mixture of 98 percent nitric acid and an equilibrium mixture of nitrogen tetroxide (N_2O_4) and nitrogen dioxide (NO_2).

FURNACE OIL: A distillate fuel primarily intended for domestic heating use. No. 1 commercial standard grade is intended for "vaporizing" burners requiring a volatile fuel, whereas No. 2 and No. 3 commercial standard grades are less volatile, and are thus usable in the "atomizing" type of burners.

G

GAGE PRESSURE: The pressure above atmospheric pressure, expressed as pounds per square inch, gage (psig).

GOB PILES: Large piles of low-combustible refuse from coal mine preparation plants. Fires may develop in these waste material piles by liberation of heat through slow oxidation, until ignition temperature is reached (see also culm).

GRAIN LOADING: Concentration of particulates in exhaust gas, expressed as grains per standard cubic foot (7000 grains = 1 pound) (see also dust loading).

GRAVITATIONAL SETTLING: Removal of material from the atmosphere due to the action of gravity.

GREEN COKE: Coke that has not been fully cooked. Green coke produces excessive emissions when pushed from a coke oven.

GREEN FEED (CALCINED FEED): Not fully processed or treated feed.

GROUT (GROUTING): A pumpable slurry of portland cement or a mixture of portland cement and fine sand commonly forced into a borehole to seal crevices in a rock to prevent ground water from seeping or flowing into an excavation or for extinguishing underground fires.

H

HEAT ISLAND EFFECTS: Meteorological characteristics of an urban area or large industrial complex which differentiates it from its surroundings. Generally, the urban area has (1) higher temperatures, (2) a less stable nocturnal lapse rate immediately above the surface, (3) lower relative humidities, (4) greater cloudiness, (5) more frequent fogs, (6) less incoming radiation, (7) lower wind speeds, and (8) greater precipitation.

HEAT RELEASE RATE: The amount of heat liberated during the process of combustion and expressed in Btu per hour per cubic foot of internal furnace volume in which the combustion takes place.

HOG FUEL BOILER: See bark boiler.

HOT BLAST MAIN: A duct lined with refractory material, through which hot air passes from a hot blast stove to the bustle pipe of a blast furnace.

HOT WELL: A reservoir for receiving warm condensed steam drawn from a condenser.

HYDRATOR-ABSORBER: A single or double tower in which phosphorus pentoxide is hydrated to phosphoric acid and the resulting acid mist is absorbed.

HYDRAULIC FLY ASH HANDLING: A system using water-filled pipes or troughs in which fly ash is conveyed by means of gravity, water jets, or centrifugal pumps.

HYDROCARBONS: Organic compounds which consist solely of carbon and hydrogen and occur in petroleum, natural gas and coal.

HYDROCRACKING: A low-temperature catalytic method of converting crude oil, residual oil, petroleum tar, and asphalt to high-octane gasoline, jet fuel, and/or high-grade fuel oil. The process combines cracking, hydrogenation, and isomerization.

HYDRODESULFURIZATION: A desulfurization process in which the oil is heated with hydrogen.

HYDROGENATION: The chemical addition of hydrogen to a material at high pressure in the presence of a catalyst.

HYDROMETALLURGY: The treatment of ores, concentrates, and other metal-bearing materials by wet processes, usually involving the solution of some component, and its subsequent recovery from the solution.

HYDROTREATING: A treating process using hydrogen for the desulfurization of cracked distillates.

I

IMPINGEMENT: In air sampling, impingement refers to a process for the collection of particulate matter in which the gas being sampled is directed forcibly against a surface. 1. Dry impingement: the process of impingement in the gas stream where particulate matter is retained upon the surface against which the stream is directed. The collecting surface may be treated with a film of adhesive. 2. Wet impingement: the process of impingement in a liquid which retains the particulate matter.

IMPINGEMENT SEPARATORS: Devices using the principle that when a gas stream carrying particulate matter impinges on a body, the gas is deflected around the body, while the particles, because of their greater inertia, tend to strike the body and be collected on its surface. The bodies may be in the form of plates, cylinders, ribbons, or spheres.

INCINERATION: The process of burning solid, semi-solid, or gaseous combustible waste.

INCINERATOR: An apparatus designed to burn solid, semi-solid, or gaseous waste leaving little or no combustible material (see multiple chamber incinerator).

INERTIAL SEPARATOR: The most widely used device for collecting medium and coarse sized particles. Inertial separators operate by the principle of imparting centrifugal force to the particle to be removed from the carrier gas stream.

INTERRUPTIBLE GAS: Gas sold whereby the seller may curtail or stop delivery, generally at his option. The gas customer under these conditions is expected to have standby equipment capable of taking over 100% of his needs by an alternate fuel.

INVERSION: A stratum in the atmosphere through which the temperature increases with height. The layer is thermally stable and vertical motion within the layer is suppressed.

INVERSION BASE: The lowest height in the atmosphere at which the temperature ceases to decrease with height.

ISOMERIZATION: A reaction which alters the fundamental arrangement of the atoms in a molecule without adding or removing anything from the original material. In the petroleum industry, straight-chain hydrocarbons are converted catalytically to branched-chain hydrocarbons of substantially higher octane number by isomerization.

J

JIG: A device which separates coal from foreign matter by means of their difference in specific gravity in a water medium. The water pulsates up and down causing the heavy material to work to the bottom.

K

KETTLE: 1. An open-top vessel used in carrying out metallurgical operations on low-melting-point metals; for example, in drossing and desilverizing lead. 2. An open or (usually) closed vessel for preparing paints, varnishes, and resins.

KILN: A furnace in which the heating operations do not involve fusion. Kilns are most frequently used for calcining, and free access of air is permitted. The raw materials may be heated by the combustion of solid fuel with which they are mixed, but more usually they are heated by gas or the waste heat from other furnaces.

KILN GAS: Hot effluent gases from a kiln. Unless controlled, these gases can be the largest source of particulates in a plant.

KNOCKOUT DRUM: A drum or vessel constructed with baffles through which a mixture of gas and liquid is passed to disengage one from the other. As the mixture comes in contact with the baffles, the impact frees the gases and allows them to pass overhead; the heavier substance falls to the bottom of the drum.

L

LAPSE RATE: The decrease of temperature with altitude.

LAUNDER: A trough, channel, or gutter usually of wood, by which water is conveyed. Specifically, in mining, a chute or trough for conveying powered ore, or for carrying water to or from the crushing apparatus.

LEACHING: Extracting a soluble metallic compound from an ore by selectively dissolving it in a suitable solvent, such as water, sulfuric acid, hydrochloric acid, etc.

LIGNITE COAL (BROWN COAL): A brownish-black variety of coal, usually high in moisture and low in Btu's. Lignite is one of the earlier stages in the formation of bituminous coal.

M

MANIFOLD: A pipe or header for collecting a fluid or gas from, or distributing a fluid or gas to, a number of pipes or tubes.

MANUFACTURED GAS: Fuel gas manufactured from coal, oil, etc., as differentiated from natural gas.

MATERIAL BALANCE: An accounting of the weights of material entering and leaving a process.

MATTE: A metallic sulfide mixture formed in smelting sulfide ores of copper, lead, and nickel.

MECHANICAL, CENTRIFUGAL SEPARATORS: A device for separating particulates. A rotating fan blade exerts a large centrifugal force on the particulates, ejecting them from the tips of the blades to a skimmer bypass leading into a dust hopper.

MECHANICAL SCRUBBER: A scrubber in which the water spray is generated by a rotating element or disk (see also scrubber).

MECHANICAL TURBULENCE: In meteorology, the induced eddy structure of the atmosphere due to the roughness of the surface over which the air is passing. The height and spacing of the elements causing the roughness will affect the turbulence.

MERCAPTANS: Organic compounds having the general formula R-SH (where R represents any hydrocarbon radical) which are analogous to the alcohols and phenols but which contain sulfur in place of oxygen. The simpler mercaptans have strong, repulsive odors.

MESH: The number of holes per linear unit in a sieve or gauze, or the space between the wires of the sieve expressed in inches or millimeters.

METRIC TON: 2204.6 pounds or 1000 kilograms.

MIST: A suspension of any finely divided liquid in a gas.

MODIFIED COAL: Coal of a stoker size containing a controlled percentage of fines.

MULTICYCLONE (ALSO MULTIPLE CYCLONE OR MULTICLONE): A dust collector consisting of a number of cyclones, operating in parallel, through which the volume and velocity of gas can be regulated by means of dampers to maintain dust-collector efficiency over the load range.

MULTIPLE-CHAMBER INCINERATOR: Any incinerator consisting of a primary combustion chamber, mixing chamber, and secondary combustion chamber in series. The chambers are separated by refractory walls, and interconnected by gas passage ports.

MULTIPLE-HEARTH TYPE ROASTER: See roasting furnace.

MUNICIPAL INCINERATOR: An incinerator owned or operated by government or by a person who provides incinerator service to government or others; a device designed for and used to burn waste materials of any and all types.

N

NATURAL GAS: Gaseous forms of petroleum occurring in nature and used directly as a fuel. Natural gas consists of mixtures of hydrocarbon gases and vapors, the more important of which are methane, ethane, propane, and butane.

NET TON: 2000 pounds (sometimes known as a "short ton").

NITROGEN OXIDES: A general term pertaining to a mixture of nitric oxide (NO) and nitrogen dioxide (NO_2).

O

ODORANT: A gaseous nuisance that is offensive or objectionable to the smell.

ODOR INTENSITY: The numerical or verbal indication of the strength of an odor.

ODOR PERVASIVENESS: The ability of an odor to diffuse into a large volume of air and still continue to possess a detectable intensity. A pervasive odor is one whose odor intensity changes very little on dilution.

ODOR QUALITY: A verbal description of an odor. The quality may be described in terms of such familiar odorants as coffee, onions, lemons, or by associating an unfamiliar odor with a familiar odor.

ODOR THRESHOLD: The lowest concentration of an odor in air that can be detected by a human.

ODOR UNITS: That quantity of odor necessary to contaminate one cubic foot of air to threshold or barely perceptible level. The number of odor units is equal to the volumes (scf) of air necessary to dilute the concentration of odorant in one volume (scf) of air to the threshold concentration.

OIL BURNER: Any device for the introduction of vaporized or atomized fuel oil into a furnace.

OIL-EFFLUENT WATER SEPARATOR: Any tank, box, sump, or other container in which any petroleum product entrained in water is physically separated and removed prior to out-fall, drainage, or recovery of the water.

OITICICA (OIL): A drying oil obtained from the kernels of the fruit of the oiticica tree that is similar to tung oil in many properties and is used chiefly in varnishes, paints, and printing inks.

OLEORESIN: A varnish or paint vehicle, made of plant oils and resins, usually cooked.

OLEUM (FUMING SULFURIC ACID): A heavy, oily, strongly corrosive liquid that consists of a solution of sulfur trioxide in anhydrous sulfuric acid. It fumes in moist air and reacts violently with water.

ONSTREAM TIME: The length of time a unit is in actual production.

OPACITY: The degree to which emissions reduce the transmission of light and obscure the view of a distant object.

OPEN BURNING: The burning of any matter in such a manner that the products of combustion are emitted directly into the ambient air without passing through a stack, duct, or chimney.

OPEN HEARTH FURNACE: Reverberatory furnace, containing a basin-shaped hearth, for melting and refining suitable types of pig iron, iron ore, and scrap for steel production.

ORE AND LIME BOIL: Reactions which occur in an open hearth furnace when carbon monoxide is produced by the oxidation of carbon. Ore boil is a violent agitation of the metal as it escapes during this process; lime boil occurs when the limestone decomposes and the carbon dioxide gas escapes. The second reaction begins before the first is completed.

ORGANIC SULFUR: The difference between the total sulfur in coal and the sum of the pyritic sulfur and sulfate sulfur.

ORGANOLEPTIC: Affecting or making an impression upon one or more of the sense organs.

ORIFICE SCRUBBERS: Devices for the removal of particulates from gas streams in which the flow of air through a restricted passage partially filled with water causes the dispersion of the water and consequent wetting and collection of the particulates.

ORSAT: An apparatus used for analyzing flue gases volumetrically.

OVERBURDEN: Material of any nature, consolidated or unconsolidated, that overlies a deposit of useful material, ores, or coal, especially those deposits that are mined from the surface by open cuts.

OVERFIRE: Air for combustion admitted into the furnace at a point above the fuel bed.

OXIDATION: The act or process of combining oxygen with a substance, with or without the production of a flame.

OXYGEN LANCING: In steel making, a procedure in which oxygen is injected into the bath of molten metal through a water cooled lance. The oxygen oxidizes carbon, silicon, manganese, and some iron in exothermic reactions. The procedure materially shortens the time needed to tap the furnace.

P

PACKED COLUMN (PACKED SCRUBBER OR PACKED TOWER): A vertical column used for distillation, absorption, and extraction, containing packing; e.g., Raschig rings, Berl saddles, or crushed rock, which provide a large contacting surface area between phases. Normally, gas flow is countercurrent to liquid flow.

PAN: Peroxyacyl nitrates. Secondary pollutants formed in photochemical oxidation and major eye irritants of photochemical smog.

PARTICLE CONCENTRATION: Concentration expressed in terms of number of particles per unit volume of air or other gas.

PARTICULATE MATTER: Any dispersed matter, solid or liquid, in which the individual aggregates are larger than single small molecules (0.0002 micrometers) but smaller than 500 micro-meters.

PERCOLATOR: A device used in rendering plants for the separation of dry proteinaceous crackling from the clear moisture-free tallow. They are generally perforated pans which allow the tallow to drain away from the cracklings.

PERFORMANCE TEST: Measurements of emissions used for the purpose of determining compliance with a standard of performance.

PETROCHEMICAL INDUSTRY: A branch of the petroleum industry in which refined crude oil is manufactured into various chemicals.

PETROLEUM COKE: See coke, petroleum.

PHOTOCHEMICAL REACTION: A chemical reaction which involves either the absorption or emission of radiation in the form of light energy.

PLUME: The path taken by the continuous discharges of products from a chimney or stack. The shape of the path and the concentration distribution of gas plumes is dependent on turbulence of the atmosphere.

POINT SOURCE: Any stationary emitting point or plant/facility whose summation of emitting points totals 100 tons (or some other fixed amount) per year of any pollutant in a given region.

POLYCYCLIC MOLECULE: A molecule containing two or more fused rings (as in anthracine).

POLYMERIZATION: 1. A reaction combining two or more molecules to form a single molecule having the same elements in the same proportions as in the original molecules. 2. The union of light olefins to form hydrocarbons of higher molecular weight. The process may be thermal or catalytic.

POLYNUCLEAR AROMATIC HYDROCARBONS: Compounds consisting of two or more aromatic rings which share a pair of carbon atoms. The simplest and most important is naphthalene ($C_{10}H_8$; also polycyclic).

PRECLEANERS: Collectors of limited efficiency used ahead of the final cleaner. If the gas contains an appreciable amount of hard, coarse particles, a precleaner can materially reduce erosive wear of the more efficient final collector.

PRECURSORS: Gaseous air pollutants which react with other substances in the atmosphere to produce different pollutants; e.g., photochemical reactions of NO and NO_2 with the oxygen of the air which produce ozone.

PRILLING: A combination spray drying and crystallization technique used in the production of ammonium nitrate. A hot ammonium nitrate solution is sprayed in the top of a tower, and air is blown in at the bottom. The liquid is converted into spherical pellets.

PRIMARY AIR: In incineration, air which is introduced with the refuse into the primary chamber.

PRIMARY EMISSION: Pollutants emitted directly into the air from identifiable sources.

PRIMARY STANDARD: The national primary ambient air quality standard which defines levels of air quality which are necessary to protect public health.

PROCESS WEIGHT: The total weight of all materials introduced into a source operation, including solid fuels, but excluding liquids and gases used solely as fuels, and excluding air introduced for purposes of combustion.

PUG MILL: A machine for mixing water and clay which consists of a long horizontal barrel within which is a long longitudinal shaft fitted with knives which slice through the clay, mixing it with water which is added by sprayers from the top. The knives are canted to give some screw action, forcing the clay along the barrel and out one end.

PUMP, RECIPROCATING: A positive-displacement type of pump consisting of a plunger or a piston moving back and forth within a cylinder. With each stroke of the plunger or piston, a definite volume of liquid is pushed out through the discharge valves.

PYRITIC SULFUR: Sulfur combined with iron, found in coal.

PYROLYSIS: Chemical change brought about by the action of heat upon a substance.

PYROMETER: An instrument for measuring temperatures beyond the range of thermometers.

R

RECOVERY BOILER: In wood pulping, a combustion unit designed to recover the spent chemicals from the cooking liquor and to produce steam for pulping and recovery operations.

REDUCTION: 1. The addition of hydrogen or the abstraction of oxygen from a substance. 2. The extraction of any metal from its ore.

REFINERY GAS: Any form or mixture of still gas gathered in a refinery from the various stills.

REFINING: In metallurgy, the removal of impurities necessary to produce an ingot or alloy of desired specification. In petroleum, the process of separating, combining, or rearranging petroleum oil constituents to produce salable products.

REFORMING: The thermal or catalytic conversion of naphtha into more volatile products of higher octane number. It represents the total effect of numerous reactions, such as cracking, polymerization, dehydrogenation, and isomerization, taking place simultaneously.

REFRACTORY: A ceramic material of a very high melting point with properties that make it suitable for such uses as furnace and kiln linings.

RERUN OIL: Oil which has been redistilled.

RESIDUAL: Heavy oil left in the still after gasoline and other distillates have been distilled off, or residue from the crude oil after distilling off all but the heaviest components.

RESISTIVITY: The property of a body whereby it opposes and limits the passage of electricity through it. Resistivity of dust is an important factor in the performance of electrostatic precipitators. If the resistivity of the collected dust is higher than about 2×10^{10} ohm-cm, excessive arcing or reverse corona can occur, thereby limiting precipitator performance.

REVERBERATORY FURNACE: A furnace with a shallow hearth; having a roof that deflects the flame and radiates heat toward the surface of the charge. Firing may be with coal, pulverized coal, oil, or gas.

RINGELMANN CHART: A standardized chart giving shades of gray by which the densities of columns of smoke rising from stacks may be compared.

ROAST: To heat to a point somewhat short of fusing, with access to air, so as to expel volatile matter or effect oxidation. In copper metallurgy, applied specifically to the final heating which causes self-reduction to occur by the reaction between the sulfide and the oxide.

ROASTER: 1. A contrivance for roasting, or a furnace for drying salt cake. 2. A reverberatory furnace or a muffle used in roasting ore.

ROASTING: 1. Heating an ore to effect some chemical change that will facilitate smelting. 2. The heating of solids, frequently to promote a reaction with a gaseous constituent in the furnace atmosphere.

ROASTING FURNACE: A furnace in which finely ground ores and concentrates are roasted to eliminate sulfur; heat is provided by the burning sulfur.

RUN OF MINE COAL: Unscreened bituminous coal as it comes from the mine.

S

SALAMANDER: A small portable incinerator, or a small portable heater burning coke or oil.

SCRUBBER: A device used to remove entrained liquids and solids from a gas stream by passing the gas through wetted "packing" or spray (see absorber).

SECONDARY AIR: Air introduced into a combustion chamber beyond the point of fuel and primary air introduction for the purpose of achieving more complete oxidation.

SECONDARY STANDARD: The national secondary ambient air quality which defines levels of air quality judged necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant.

SINTERING: A heat treatment that causes adjacent particles of material to cohere or agglomerate at a temperature below that of complete melting.

SKIMMING PLANT: An oil refinery designed to remove and finish only the lighter constituents from the crude oil, such as gasoline and kerosene. In such a plant the portion of the crude remaining after the above products are removed is usually sold as fuel oil.

SKIP HOIST, INCLINED: A bucket or can operating up and down, receiving, elevating, and discharging bulk materials.

SLAG: The non-metallic top layer which separates from the metallic products in smelting of ores.

SLOP OR SLOP OIL: A term rather loosely used to denote odds and ends of oil produced at various places in a plant, which must be rerun or further processed in order to get in suitable condition for use. When good for nothing else, such oil usually goes into pressure-still charging stock, or to coke stills.

SMELT: In wood pulping, the molten chemicals from the kraft recovery furnace consisting mostly of sodium sulfide and sodium carbonate.

SMELTING: Any metallurgical operation in which metal is separated by fusion from impurities with which it may be chemically combined or physically mixed, such as in ores.

SMOKE: Small gas-borne particles resulting from incomplete combustion, consisting predominantly but not exclusively of carbon, ash, and other combustible material, and present in sufficient quantity to be observable.

SMOKE CANDLE(S): Apparatus used in collecting acid mists. Tubes or candles made from glass or plastic fibers are pressed into pads with thicknesses up to 2 inches and mounted in banks. Efficiency is much increased when the glass is treated with silicone oil to repel water, or when normally water-repellent plastic is used.

SMOKE UNIT: The number of "smoke units" is obtained by multiplying the smoke density in Ringelmann numbers by the time of occurrence in minutes. For the purpose of this calculation, a Ringelmann density reading is made at least once per minute during the period of observation. The sum of the Ringelmann density readings (made once per minute) during the period of observations would equal the number of smoke units.

SOILING: Visible damage to materials by deposition of air pollutants.

SOOT: Agglomerated particles consisting mainly of carbonaceous material.

SOUR: Gasolines, naphthas, and refined oils are said to be "sour" if they show a positive "doctor test"; i.e., if they contain hydrogen sulfide and/or mercaptans. Sourness is directly connected with odor, while a "sweet" gasoline has a good odor.

SOURCE: Any property, real or personal, or person contributing to air pollution.

SOURCE SAMPLE: A sample of the emission from an air contamination source, collected for analysis from within a stack.

SPARK ARRESTOR: A screenlike device to prevent sparks, embers, and other ignited materials larger than a given size from being expelled to the atmosphere.

SPEISS: Metallic arsenides and antimonides smelted from cobalt and lead ores.

SPRAY CHAMBER: The simplest type of scrubber consisting of a chamber in which spray nozzles are placed. They are used extensively as gas coolers because they have a low collection efficiency for anything but coarse particles.

STABILITY (STATIC STABILITY): The state of the atmosphere when it is stable relative to vertical displacements.

STACK OR CHIMNEY: Any flue, conduit, or duct arranged to conduct an effluent to the open air.

STACK SPRAY: A nozzle or series of nozzles installed in a stack above the breeching, used to inject wetting agents at high pressure to suppress the discharge of particulate matter from the stack.

STANDARD CONDITIONS: For source testing, 70°F (21.1°C) and 29.92" Hg (760mm Hg); for air quality measurements, 77°F (25°C) and 29.92" Hg (760mm Hg);

for chemistry, 273.1°K (0°C) and one atmosphere (760mm Hg); for petroleum refining, 60°F (15.55°C) and 14.7 psi (760mm Hg).

STATIONARY SOURCE: Any non-mobile building, structure, facility, or installation which emits or may emit any air pollutant.

STEAM DISTILLATION: Introduction of "open" steam into the liquid during distillation to assist in vaporizing the volatiles at a lower temperature.

STILL: A closed chamber, usually cylindrical, in which heat is applied to a substance to change it into vapor, with or without chemical decomposition. The substance, in its vapor form, is conducted to some cooling apparatus where it is condensed, liquefied, and collected in another part of the unit.

STOCK: In general, any oil which is to receive further treatment before going into finished products.

STOKER: A machine for feeding coal into a furnace, and supporting it there during the period of combustion. It may also perform other functions, such as supply air, control combustion, or distill volatile matter. Modern stokers may be classified as overfeed, underfeed, and conveyor. Any mechanical device that feeds fuel uniformly onto a grate or hearth within a furnace may be termed a "stoker."

STOPING: In mining, any process of excavating ore which has been made accessible by shafts and drifts.

STRAIGHT-RUN DISTILLATION: Continuous distillation which separates the products of petroleum in the order of their boiling points without cracking.

STRIPPER: Equipment in which the lightest fractions are removed from a mixture. In a natural-gasoline plant, gasoline fractions are stripped from rich oil. In the distillation of crude petroleum, light fractions are stripped from the various products.

SUBSTITUTION: A chemical reaction in which one or more atoms or groups of a molecule are replaced by equivalent atoms or groups to form at least two products, especially the replacement of hydrogen in an organic compound by another element or group.

SULFIDITY: An expression of the percentage makeup of chemical kraft cooking liquor obtained by the formula

$$\frac{Na_2S}{Na_2S + NaOH} \times 100$$

where the sodium compounds are expressed as Na_2O.

SUPERPHOSPHATE: Products obtained by mixing phosphate rock with either sulfuric or phosphoric acid, or both.

SURFACE CONDENSERS: A condenser in which the coolant does not contact the vapors or condensate. Most are of the tube and shell type. Water flows inside the tubes and vapors condense on the shell side.

SURGE TANK: A storage reservoir at the downstream end of a feeder pipe to absorb sudden rises of pressure and to furnish liquid quickly during a drop in pressure.

SWEETENING: The process by which petroleum products are improved in odor and color by oxidizing or removing the sulfur-containing and unsaturated compounds.

SYNERGISM: Cooperative action of discrete agents such that the total effect is greater than the sum of the two effects taken independently.

SYNTHETIC CRUDE: The total liquid, multi-component mixture resulting from a process involving molecular rearrangement of charge stock. Term commonly applied to the product from cracking, reforming, visbreaking, etc.

T

TAIL OIL: That portion of an oil which vaporizes near the end of the distillation; the heavy end.

TAIL GAS: The exhaust or waste gas from a process.

TALLOW: The rendered fat of animals that is white and almost tasteless when pure, composed of glycerides of fatty acids containing a large proportion of palmitic acid and stearic acid, and that is used chiefly in making soap, glycerol, margarine, candles, and lubricants.

TAPPING: Removing molten metal from a furnace.

TEMPERATURE INVERSION: An atmospheric layer in which temperature increases with altitude. The principal characteristic of a temperature inversion is its marked static stability, so that very little turbulent exchange can occur within it (see also inversion).

THEORETICAL AIR: The exact amount of air (stoichiometric air) required to supply the oxygen necessary for the complete combustion of a given quantity of a specific fuel or refuse.

THERMAL TURBULENCE: Air movement and mixing caused by temperature differences.

TOPPED CRUDE PETROLEUM: A residual product remaining after the removal, by distillation, of an appreciable quantity of the more volatile components of crude petroleum.

TOPPING: The distillation of crude oil to remove light fractions only.

TOTAL REDUCED SULFUR COMPOUNDS (TRS): Malodorous gases produced in the wood pulping industry exclusive of sulfur oxides. TRS usually includes hydrogen sulfide (H_2S), methyl mercaptan (CH_3SH), dimethyl sulfide (CH_3SCH_3), and dimethyl disulfide (CH_3SSCH_3). The concentration of TRS is usually expressed as H_2S regardless of the constituent compounds.

TURBULENCE: Atmospheric motions which produce a thorough horizontal and vertical mixing of the air.

TURNAROUND: The time between shutting down and starting up of process equipment for repair or maintenance.

TUYERES: Openings or nozzles in a metallurgical furnace through which air is blown as part of the extraction or refining process.

TWADDELL DEGREES (°TW): A measure of acid density and strength:

$$°TW = \frac{\text{sp. gr. } (60°/60°F)}{0.005}$$

Each twaddell degree corresponds to a specific gravity interval of 0.005.

U

ULTIMATE ANALYSIS (OF COAL): Contains the following, expressed in percent by weight:

Carbon	(C)	%
Hydrogen	(H_2)	%
Sulfur	(S)	%
Oxygen	(O_2)	%
Nitrogen	(N_2)	%
Moisture	(H_2O)	%
Ash	(H_2O)	%
		100.0%

UNDERFEED STOKER: A stoker consisting of a trough or pot-shaped report into which coal is forced by an endless screw or ram. Coal is fed to the fire zone by being pushed up from underneath.

UNIT OPERATION: 1. Methods by which raw materials may be altered into states, such as vapor, liquid, or solid without being changed into new substances with different properties and composition. 2. Recognition, study, application and control of the principles and factors utilized in a distinct and self-contained process (for example, filtration). This avoids the duplication of effort which attends the study of similar processes as though each process involved a unique set of principles.

UNIT PROCESS: 1. Reactions where raw materials undergo chemical change. 2. See unit operation (2).

UREA FORMS: A urea-formaldehyde reaction product that contains more than one molecule of urea per molecule of formaldehyde.

V

VACUUM JET (STEAM JET EJECTOR): A fluid nozzle that discharges a high velocity jet stream across a section chamber that is connected to the equipment to be evacuated. The gas in the chamber is entrained by the jet stream.

VAPOR: The gaseous phase of a substance that generally exists as a liquid or solid at room temperature.

VAPOR PLUME: The stack effluent consisting of flue gas made visible by condensed water droplets or mist.

VAPOR RECOVERY SYSTEM: System used in petroleum refining for separating a mixed charge of miscellaneous gases and gasolines into desired intermediates for further processing.

VENTURI SCRUBBER: A type of high energy scrubber in which the waste gases pass through a tapered restriction (venturi) and impact with low-pressure water. Gas velocities at the restriction are from 15,000 to 20,000 fpa and pressure drops from 10 to 70 inches water gage.

VISBREAKING: Viscosity breaking; lowering or "breaking" the viscosity of residual oil by cracking at relatively low temperatures.

VISIBILITY: In United States weather observing practice, the greatest distance in a given direction at which it is just possible to see and identify with the unaided eye (a) in the daytime, a prominent dark object against the sky at the horizon, and (b) at night, a known, preferably unfocused, moderately intense light source. After visibilities have been determined around the entire horizon circle, they are resolved into a single value of prevailing visibility for reporting purpose.

VISIBLE EMISSION: An emission of air pollutants greater than 5 percent opacity or 1/4 Ringelmann.

VOLATILE OR VOLATILE MATTER: 1. The gasoline constituents that can be driven off liquids and solids by the application of heat. 2. Specifically for coal, that portion which is driven off in gas or vapor form when coal is subjected to a standardized temperature test.

VOLATILE ORGANIC COMPOUNDS: Any compound containing carbon and hydrogen or containing carbon and hydrogen in combination with any other element which has a vapor pressure of 1.5 pounds per square inch absolute or greater under actual storage conditions.

W-X-Y-Z

WASTE HEAT BOILERS: Boilers which utilize the heat of exhaust gas or process gas to generate steam or to heat water.

WEAK WASH: In wood pulping, a liquid stream in the kraft process which results from washing of the lime mud.

WET COLLECTORS: Devices which use a variety of methods to wet the contaminant particles in order to remove them from the gas stream (see scrubbers).

WET FILTERS: A spray chamber with filter pads composed of glass fibers, knitted wire mesh, or other fibrous materials. The dust is collected on the filter pads.

WHITE LIQUOR: Cooking liquid used in the wood pulping industry. Kraft process: consists of approximately 1/3 sodium sulfide (Na_2S) and 2/3 sodium hydroxide ($NaOH$). Sulfite process: consists of sulfurous acid plus one of the following: calcium bisulfite, sodium bisulfite, magnesium bisulfite, or ammonium bisulfite.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1972—748763/4111

ENVIRONMENTAL PROTECTION AGENCY
Technical Publications Branch
Office of Administration
Research Triangle Park, N.C. 27711

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